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Institution

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THE

TRANSACTIONS

OF THE

INSTITUTION OF CIVIL ENGINEERS

OF IRELAND.

SESSIONS 1855–8.

VOL. V.

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ALEXANDER TATE, MEM. INST. C.E.I.,

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The Editor is directed to state, that the Authors alone are responsible for the facts and opinions expressed in their several communications.

TRANSACTIONS

OF THE

Institution of Civil Engineers of Ireland.

TRANSACTIONS

OF THE

INSTITUTION OF CIVIL ENGINEERS

OF IRELAND.

[January 9, 1855.]

RICHARD GRIFFITH, Esq., LL.D., President, in the Chair.

Observations on River Walls and Flood Banks, *in the Upper Rhine and its Tributaries;* by G. W. Hemans, V.P. Inst. C.E.I.

The author of the following remarks does not presume to offer them to the Institution as representing a regular paper or memoir. Too much engaged in employments, at widely separate points, his time gives little leisure for the pen.

The accompanying diagram map, drawing No. 1,* will indicate the course of a railway something over 200 miles in total length, laid out in Switzerland under his directions. The portion coloured red, 100 miles long, is under contract; the remainder, coloured blue, is about 100 miles more in length, and its line and works have recently been surveyed and estimated by the author; but the latter being of quite a gigantic character, involving a tunnel through the Alps, it is not expected that more than the easiest part will be under-

* The drawings referred to in this paper, were presented by Mr. Hemans, and are to be seen in the Library of the Institution.

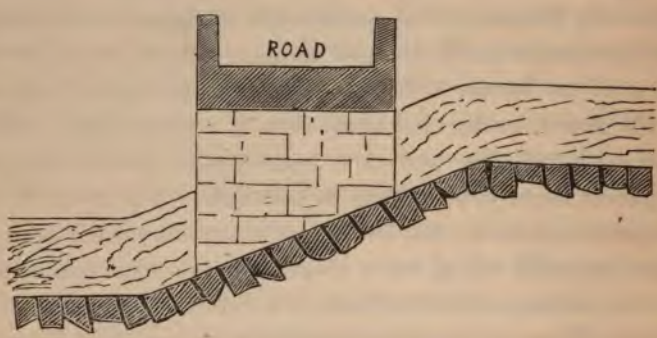
taken at present. The importance of the entire chain could scarcely be over-rated—connecting, on the north, with the whole system of French and most of the German lines, it would convey their European traffic to all the southern states, and further, to Egypt and India. There are now excellent steamers on the lakes of Zurich and Maggiore, but these would no doubt be eventually superseded by railways on the shores of those lakes. It will be seen that the South Western terminus of the chain leads direct to Genoa, the South Eastern to Milan, and eventually to Rome and Naples.

The author does not here intend to enter into any consideration of the proposed method of crossing the Alps; but, as a matter of curiosity, he submits to the meeting a profile section taken over the Lukmamier Pass, by his assistants. The summit is 6,250 feet above the sea. This the author believes to be the first accurate section ever made across the Alps with a spirit level.

Referring to the northern portion of the line, commencing on the one hand at the Lake of Zurich, on the other at the Lake of Constance, it will be seen that for more than 60 miles it follows the course of the great river Rhine—here called the Upper Rhine. The river presents very remarkable features. Flowing through a magnificent valley, varying from one to five miles wide, the adjacent limestone cliffs rise from 1,500 to 2,500 feet above its bed. These cliffs bear the most striking marks of denudation, or rather decrementation, from the constant melting of snows and beating of storms of wind and rain. The bed of the river, in its entire length, is composed, to an unknown depth, of the detritus from these rocks in the shape of limestone gravel. Into this bed, which varies from 500 to 2,000 feet wide, numerous lateral torrents discharge themselves from the mountains; every torrent brings down constant accessions of detritus, and these accumulations drive the main river from side to side, causing a very tortuous

course, and gradually raise its bed from year to year. The torrents sometimes come down with tremendous force; storms, called "temporales" occur, during which heavy rain-falls bring down a quantity of the soft limestone, and very generally the contents of considerable catchment basins among the mountains are discharged through narrow gorges at the base of the harder cliffs. In the gorges the torrent, charged with gravel, rocks, and trees, rises to a great height, rushes out with violence, and then immediately spreads over the adjacent country, depositing its materials. The result of this perpetual action is, that the bed of every torrent has been for ages gradually rising, and is always found on a summit, instead of the natural position of water, in a valley. The main valley of the Rhine is therefore subdivided into a series of cross valleys and ridges alternately; on the ridges flow the torrents among dibris and devastating detritus, while the valleys are dry, green, and clothed with vineyards. Some of these cross ridges are hundreds of feet high of gravel detritus, and their lateral slopes extend as far as a mile on each side. Great art is evinced by the natives in confining the torrents to the summits of their own deposit ridges, but they are by no means always successful. Walled channels, with paved troughs, channels faced with smooth boards to allow the rapid sliding off of detritus, even wattle-sided courses, where means are limited, are all employed to convey the dreaded torrents evenly to the great receptacle of all their contents, the Rhine. These channels are kept as narrow, deep, and with as great a fall as possible; the object is to give the water power to carry along with it the heavy materials which, if deposited, check the torrent and cause its overflow. When large trees are torn up by the whirlwinds—here called "torments"—and carried down the torrents, the dykes are generally broken, and sometimes the labour of years on the adjacent grounds is destroyed in half an hour. The public road which traverses the valley,

is intersected in many places by the torrents; openings, with paved shoots, generally convey them under the road.—(*See Sketch.*)



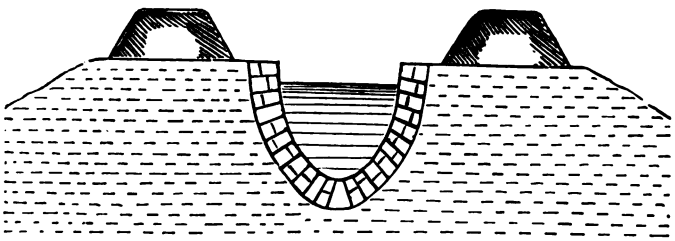
When these become choked, the road is instantaneously buried several feet deep in detritus, and at the season of the storms, men are constantly on the watch to excavate a passage for the mails, &c.; notwithstanding, they are sometimes compelled to turn back and wait for hours.

The railway will also cross the torrents in many places; and the author has anxiously considered the best means of avoiding the chance of entire dislocation and rupture, or the burying up of his permanent way under these currents of mud, gravel, wood and water. Their approach is so sudden, that serious accumulations might occur almost in view of a train before it could be stopped.

In one instance it is intended to tunnel under the gravel ridge of a torrent, in all the others the safest plan seems to be to keep as high above them as possible, and to make the line close to the main river where the ground is comparatively flat, and the torrents lose their force. It has been also decided to straighten, guide, and enclose the course of every torrent passed, for a considerable distance above the railway; if possible

quite up to its point of sortie from the mountain and under the railway to some distance below.

The form of channel adopted by the author is thus:—



The bottom being egg-shaped, as now commonly adopted for sewers, and, as well as the sides, paved with stones 18″ deep—the material excavated is heaped up on either side in order to provide against over-flow. These channels are to be made from 6 feet to 10 feet wide, deep in proportion, and as straight as possible. In that country, with the materials at hand, they can be made on the average, for 20s. per lineal yard.

The upper width between the spoil banks will allow of the passage of trees, while the contracted bottom will give power to the current to bear along its heavy materials in motion. When approaching the railway the fall of the bed is suddenly increased so as to ensure a double velocity, and thus it is expected that all substances will be forced under the arches and no accumulation can arise to overtop or bury the works.

Drawing No. 3 will convey some idea of a portion of the bed of the Rhine with the side torrents. When the snows melt, and the water is high, the whole bed from bank to bank is full; to prevent overflow of the adjoining lands, which are lower at some distance from the river than close to it, earth dams are raised all along the banks and following their irregular course, as indicated by the lines B. B. B. These

are but slight affairs, about 3 feet wide on top and with slopes of 1 to 1, and sometimes less; the consequence is that they not unfrequently burst, and in 1853 this occurred, and the author saw the whole valley for miles under water. When the water is low, which is in winter, the bed of the river presents the appearance shown in the drawing, and which is common to all untutored rivers flowing on gravel beds; the scale of this one being unusually great, the expanse of gravel sometimes 2,000 feet wide, intersected by streams in every direction, and changing with every flood, is very remarkable. Besides the damage by overflow a great deal of land is obviously wasted by this wild spreading of the river: consequently the inhabitants are most desirous of confining the entire river within prescribed lines, strengthening its course, and improving the fall.

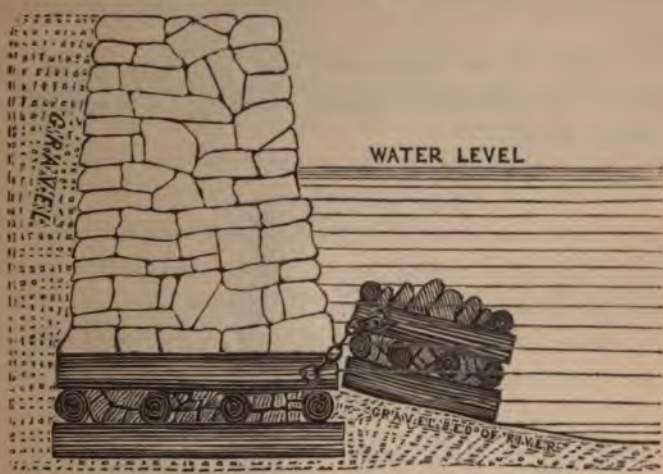
This being a work of immense magnitude can only be carried out in detail and commencing with the most pressing portions. It is done very gradually by the communes, or parishes, which are compelled by the government to contribute each a certain amount of labour and stone, &c., per annum.

400 feet has been determined on for the width of the corrected river; and in many places the new channel has to be carried, as shown by the dotted lines on drawing No. 3, through the centre of the present labyrinth of currents and shoals.

It will easily be understood that to erect, on a loose and shifting gravel bottom, dykes capable of confining this mighty river at flood level is a serious undertaking. To attempt it in detached portions, where the ends of the walls would be opposed to the current, would be madness. It is therefore only done by commencing at situations where a projecting rock or firm bank fixes a point in the new course, and thence the work is slowly carried on down stream.

The form and structure of these river walls varies; but the

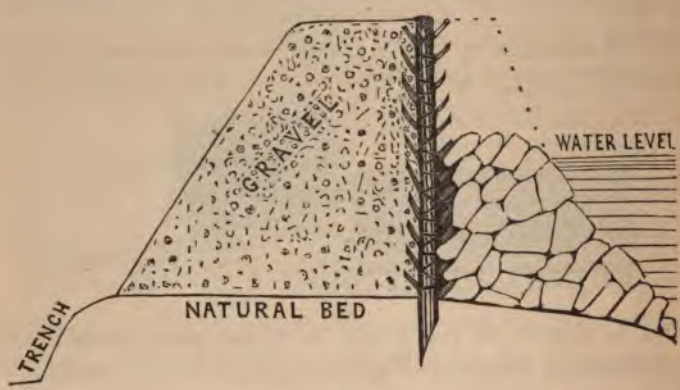
following are examples of some that the author saw in progress, and they will be found to possess some interest:—



No. 1. Section at top from 6 to 10 feet wide, about ¼th to 1; foundation, rough trees spiked together into a "treillage," and the hollows filled and wedged up with stones; height of wall from 10 to 15 feet. The foot of such a wall has been found by experience to be very soon undermined, and the wall consequently subsides, from the powerful current at its base which every new guiding line in running water has to encounter. The ingenious and simple apparatus at the toe of the wall is the local remedy found to be most effectual at a moderate cost; it is a loose frame-work, also made of trees, spiked together and filled and weighted with large stones; this is laid in detached lengths all along the foot of the new wall. As the currents wear the gravel at the outside edge of this frame, the latter sudsides gradually, and thus accommodates itself, without damage to the wall above, to the altered bottom; when the frame has sunk considerably it very generally becomes a kind of fixed apron well embodied in the gravel, no longer moved by the currents, and a sufficient

protection to its wall above. The currents being more hurtful while the work is in progress than after its completion, this simple arrangement is well suited to its partly temporary object.

The trees in the stone-work very generally throw out branches and stems of new bushes, which appear to consolidate the whole work.—



No. 2 is another system, and is equally simple, economical, and ingenious, though the author confesses that he was much surprised at the hardihood of its idea in some respects.

When the river is very low, a number of hazel and other poles, in their rough state, and not more than 2 to 3 inches diameter, and 10 to 12 feet long, are pointed and stuck in the gravel, in the line of the intended dyke; these are then all strongly wattled together with rods and boughs twisted in and out. A large gang of men now proceed to make a wide trench in the gravel, at some distance, in a parallel line behind the wattle-wall, the material excavated is heaped as quickly as possible behind the wattles, to a width of 12 or 15 feet on top—slope, $1\frac{1}{2}$ to 1. It is surprising to see the fragile boughs sustaining, vertically, a fresh embankment of gravel often 12 feet high. Along the top of the bank thus formed, carts of

stone at once begin to ply, and their contents are dropped over the edge of the wattle-wall, and left to assume, in the first instance, their natural slope. This operation is continued until the whole front is protected, and then the work is left to the action of the floods till the next dry season. Afterwards, at leisure, the stones thrown over are sorted and roughly built together, so as to form an even pitched surface, and the toe is protected by an extra deposit of stone.

It is obvious that the utmost expedition is necessary in this mode of erecting the dyke, as the least fresh in the river would carry away every portion not protected by the stone-work; very numerous gangs of men and horses are consequently employed. The beneficial result is the rapid formation of a cart-road, high and dry, along which a large bulk of stone can be conveyed, and easily tipped over to its required position. The natives are so well acquainted with the signs of the weather, that they are very seldom surprised and injured by floods before the protecting cover is complete.

The author, besides carrying the line of railway by a bridge over the Rhine, is obliged, in several instances, to form it in the bed of the river on the gravel shoals—he has not the intention of adopting either of the Swiss plans of embankment. His line is single, and he means to try the common form of a bank, 18 feet wide at top, well raised above the floods, and with slopes of 1½ to 1. These slopes to be clothed with a pavement 18″ deep, well sunk at foot under the gravel bed.

It is considered that this form of section, as containing a greater substance of material than a more vertical wall, may present less risk of sudden subsidence and danger to the permanent way, while the flatness of the slope, and depth of the toe under the gravel, will be a safeguard against the action of currents.

None of this part of the work is yet in progress, but it is

about to begin; and the author will be happy to hear the suggestions of any member on the subject.

The plain paved slopes have been successfully used by the author on the Dublin and Drogheda and Galway Lines, to resist a very heavy sea; but it is not quite so certain that they are suited to a longitudinal current.

In conclusion, it may be of interest to mention the cost of the river walls as built by the Swiss. The gravel banks are heaped up at the rate of about 4*d.* per cubic yard; the stonework about two francs, or 1*s.* 8*d.*, per ton or load. It is stated to the author that the average cost of the main dykes is about 100 francs, or £4, per lineal metre, *i. e.*, about 3 feet 3 inches in length.

[29th May, 1855]

THE PRESIDENT IN THE CHAIR.

SINGLE *and* DOUBLE LINES *of* RAILWAY; by JOHN BOWER, M.I.C.E.I.

IN fulfilment of a promise made in this Institute during last session, I have the honor to bring before this meeting the question of the comparative merits of single compared with double lines of railway.

This question was first raised in this Institute by Professor Lane, of the Cork College, in a paper descriptive of works on "The Amsterdam and Rotterdam," or "North Holland Railway," (which he had visited in August, 1851,) read at the Institute on the 13th of January, 1852.

In this paper, after an interesting description of works, and a statistical relation of the circumstances of the district of the railway, the author, like a true patriot, sought to introduce to his own country the improvements and benefits which he had seen and felt in a foreign land; and he concluded his paper with the following statement, viz.:—"That single lines of railway are fully adequate to the requirements of general railway traffic in Ireland," and that "all expenditure beyond the single construction is a dead weight upon railway stock."

On the 30th of March, 1852, Mr. Hemans, V.P., produced his "Remarks on that part of Professor Lane's paper relating to single and double lines of railway."

In the following season (8th March, 1853,) Professor Lane's paper on Belgian Railways appeared; in which he describes, graphically, the system of railways in that country, as well as some of the chief works in detail—enforces the application of the principles so successfully carried into execution in that kingdom, and adds to the weight of evidence in his former paper in favor of single lines as applied to Ireland.

A conversation followed, in which very opposite views were put forth; in consequence of which one of the ordinary general meetings of the Institute was set apart for the discussion of this most important subject.

This meeting and discussion proved a failure; and thus one of the most important subjects that could engage an Irish institute, Irish shareholders, or Irish engineers, would have been set aside, had it not been for the PROTEST entered during last session, from the Presidential chair, against the views put forward, so ably, in Professor Lane's contributions on Dutch and Belgian railways!

At the meeting at which the protest was put in, and accepted, I had the honor of being present; and, regretting the fate of the paper, and anxious that the subject should be fully and fairly discussed, had the temerity to volunteer the contribution before you.

In the conversation which followed upon Professor Lane's papers, and Mr. Hemans' remarks, it was frequently put forth by the latter, and others who were the exponents of similar views, that this single and double way discussion was a *shareholder's* question, and not an *engineering* question; and that the attempt to look at it in a financial aspect was an unprofessional treatment of the subject.—(*See Transactions* 30*th March*, 1852: "The Chairman.—A professional paper should be discussed on professional grounds. The question appeared to be—Is it equally GOOD and SAFE to WORK single and double lines.")

These observations were in reply to the able and experienced engineer of the Kingstown Railway, who spoke of the depreciation of railway stock, and the lowness of dividends consequent on extravagant or needless construction.

Now, so far from this being beside the question, it appears to me to be its very soul! and whether as a shareholder's or an engineer's discussion, COST is a point of the first consideration.

Without shareholders we can have no works, without works we should be without an occupation for the engineer; thus, we cannot separate the interests of the two—what is a shareholder's question must be an engineer's question—for the former is dependent upon the latter; and what is an engineering question must become a shareholder's question—for the latter relies for the embodyment of his genius, as well as for his daily bread, upon the former.

If we cannot produce railways at prices which will make them desirable investments for shareholders, or, at least, as good as other investments for their capital, we can never have them to that extent to which they otherwise would exist. The art or manufacture that is ruinous to its practiser or producer cannot, in the nature of things, flourish; and, although the newness of a system, or a discovery in an art may, at first, insure, among an enlightened or refined people, a certain amount of success, independent of its cost; unless it is reproductive of the capital required in its support, it must, in the end, fall into disuse, or be crippled in its progress.

A government may *force* railways in a nation, by a great sacrifice of money, as in the case of France and Russia, and secure receipts to proprietors, by the local baronial taxation of a people, as in the extension to Galway; but, so long as railways are to be the pure commercial enterprises which they ought to be, and save in certain supervisions apart from, and independent of, the State, the consequences of treating the question *away* from its financial aspect must fall most seriously upon the companies who submit to it—in part on the engineers, who are deprived of employment by it—but principally upon the remote communities, who are locked up by it—who are, by it, barred of what is good, and useful, and sufficient for their wants, because they cannot afford to have what is more costly and magnificent.

I shall, depending upon your patience more than on my

own ability, treat the subject in its threefold aspect, and in the following order, viz., of *Safety*, *Efficiency*, and *Cost*.

First, then—*Are single railways as safe as double lines?* I believe I shall best discuss this branch of the subject by first answering the objections already made, and protested against the single system. It is alleged that "single tracks, where the works are double, cannot be safely used where several lines of railway work into and over each other—that excessive danger will ensue at all junctions—that they can be only employed where lines are tolerably straight and level, and the management entirely under one control." Now, the traffic working into or over a line is, of necessity, always as well known and understood by the manager as that traffic strictly belonging to his own line; and, as it is not the practice to work ANY traffic at random, and without mutua pre-arrangement, it only becomes as so much more traffic to be accommodated by additional stock, sidings, or such an alteration of time-tables as will ensure safety and harmony in the working of the whole system.

With regard to the danger at junctions. Great care must be taken in the double as well as in the single way in the management and working of the traffic, to avoid collisions at junctions (*as well as at every other point of a line*), and that the necessary sidings be arranged for the reception of trains at all points of intersection; and, accompanied with proper arrangements as to time, this system is rightly held by all single-track advocates to be safer than the double way: in return for which safety passengers are sometimes called upon, at sidings and in stations, to make a slight sacrifice of *patience*—seldom of *time* in the whole journey—consequent upon the slight inaccuracy that must occasionally arise in the meeting and passing of trains.

But it is stated that, "unless lines are straight and level, single tracks cannot be used." What difference there is against

curves on single lines, beyond the mechanical disadvantages that exist on double lines, I cannot pretend to imagine! An obstacle accidentally or maliciously placed, a slip in cutting or embankment, or a bridge carried away, is an occasional evil which cannot be guarded against; and such a circumstance, occuring upon a sharp curve, might cause, on a double line, injury or destruction to TWO *trains*, whereas, on a single-track railway, only *one* could suffer. But such an accurate meeting of trains for destruction would only be by most intelligent malice, or at exceedingly rare intervals; so that, in this respect, I look upon the systems as equal.

I need not tell this meeting that, with proper management, no two trains should meet or overtake each other on the same line; and, acting on this principle, it is the practice not to grant special trains when there is any reasonable risk of such an event.

There may exist some inconvenience in working a single line *over steep gradients*, beyond what might be in the double-track system.—Thus the situation of such passing places as might be desirable for the working of the traffic, according to certain hours of departure and arrival, might fall, inconveniently, *on* inclines where stations might not be necessary, and thus increase the difficulty of stopping, and the wear and tear of the stock and road; but, *considered in relation to the additional* DANGER alleged to ensue, it is wholly imaginary; and with such an arrangement of short and well balanced inclines as should be a desideratum in the execution of works, it will be an easy matter to overcome the difficulty.

It is stated that "it is obviously more dangerous to use a single track, with frequent sharp curves and inclines," and the *object* of avoiding such curves and gradients is stated to be, "that engines can recede from each other in time."

From this sage objection one might suppose (in the absence of any other knowledge) that it was the practice to send

engines and trains out, depending altogether upon the instincts, the second sight, or the look-out of engine-drivers. But, knowing that no train or engine is suffered to go on a line without pre-arrangement, or a perfect knowledge of the movements of all the trains upon the railway, it is obvious that a collision, under such circumstances, can only occur by some unfortunate accident or oversight, which would be as likely to occur upon the double as on the single line.

It is also stated that, "on single lines, slow trains must put into sidings, and wait a long time, to keep out of the way of fast trains; and at points where up and down trains meet, on a long single line, the slightest casualty is sure to cause a long delay to one of them." The objection applies equally to *single and double lines!* It is an axiom in railway management, that if all trains travelled at the same rate, and in the same direction, collision would be impossible! But the chief difficulty in managing a large traffic, is the unequal speeds at which trains must travel; and out of this circumstance, also, arise most of the accidents that occur on railways. Thus engines, getting disabled, and the trains they convey losing time, and being run into by trains coming after, is a frequent source of danger. But, in this respect, the single system has the advantage! for, sidings being distributed at short distances, for the passage of trains, a disabled engine would, in most cases, be able to take shelter in one of them, and remain safely till the passing of the faster, or following train, when a flag of distress could be seen, and assistance rendered, or sent back from the next station: whereas, with the double track, it might be impossible to reach such a haven, until a fatal collision occurred—the occurrence of which, lamps and signals have so often failed to prevent.

With regard to the other part of the statement, alluding to the "delay to one of the trains in case of any casualty occurring," this must be admitted! But let me ask, where is the

passenger, travelling in a train on the *up* line of the double system, who would madly wish to proceed past the scene of an accident on the *down* line, ignorant of its nature and extent? Would we not all prefer lying quietly and safely in the siding —*losing time*, and *saving our lives*—to the glorious ignorance and risk of dashing past the scene of the disaster? But does it not happen every day that, on the best double lines in the world, slow trains must put into sidings, and wait for the passing of faster trains? To avoid this inconvenience, if it be one, four lines would not be enough for the varied traffic of even an ordinary railway.

At Swindon, for example—the great station of the greatest line in the world—at Crewe, at Birmingham, at Wolverhampton—in the management of the greatest proprietary in the world—the observing traveller may see it every day occur; and, "in case of casualty," there also would there be serious delay, and, moreover, a delay which no sane man would wish to break until the line was reported safe and clear.

With regard to the statement that, "to work single lines, the management should be entirely under one control." This state of things would be desirable *in all cases*—in double as well as single railways, *if it were possible.* Out of divided direction, and the consequent squabbles of railway boards, come great inconvenience to the public, as was lately illustrated in the case of the Drogheda, Junction, and Ulster Companies, where even the oil for lighting the carriages used on the journey from Belfast to Dublin, was the subject of such serious misunderstanding that, a short time since, each company had its own set of lamps, which were regularly changed at the junctions: the directors or their officers being wholly unable to settle amicably the division of this magnificent item of expenditure.

Heretofore there has been great difficulty in getting proper public accommodation from railway companies, but this is fast

disappearing. It must be for their mutual benefit to work together for the perfect accommodation of the public; save, perhaps, in a few exceptional cases, where rival schemes create conflicting interests, and even in these cases, in future, the law will at all times prevent such arrangements, as will produce danger to the living cargoes transported by them.

I cannot see, however, that divided direction will act injuriously in the case of single over double lines. It will, doubtless, increase the number of sidings and the difficulty of adjusting the trains a little, but with the intelligence and energy, which should characterize the management of every railway, it cannot increase the *danger* of working the traffic over the road.

There are two classes of accidents occurring on railways, viz., those which arise from imprudence, and those beyond the control of the sufferers.

With regard to the former, a double line might appear to afford a greater breadth for accidents of this class. For instance, a large proportion of the accidents that occur, are from passengers thoughtlessly getting out on the wrong side, and being run over by a train on the other line; in trespassers crossing railways; or in the case of passengers crossing at railway stations. However, when we take into account that the same number of trains must always pass the same points, whether on one line or two lines, it reduces the risk in both to equality. Besides, this is a class of accident which cannot be chargeable to railway management, and therefore need not enter into the discussion of the merits of the respective systems.

The class of accidents which are beyond the control of the sufferers, are those which should be the subjects of railway legislation and management; and if single lines were found to be more productive of such calamities, it would be a strong argument against their use; not, however, with reasonable

communities or engineers to prevent their adoption, but to be a reason calling for greater caution in their use and management.

But we do not find that such is the case. The greater punctuality, necessary to the working of single lines from station to station, is the best safeguard against accidents of this class.

The single lines of Belgium, of Prussia, and Germany—of France, of America, and of the United Kingdom, possess extraordinary immunity from collision, when compared with the double lines of England. And, when we look for the localities of great accidents, we find them on the best double lines in these countries; and up to the present time, I am not aware of any serious accident having occurred upon the 400 miles of single line in Ireland. Nearly all the bad accidents which have occurred, within the control of companies, on double or single lines, have sprung from *mismanagement, disobedience of orders,* or *want of intelligence in driving!* Of the first class, may be mentioned, the carelessly leaving a horse-box on the rails, at the Shrivenham station of the Great Western Railway, by which six persons were killed, and thirteen wounded.

Of the second and third, the accident at Straffan, where recklessness with regard to time, and to the strict look-out always required, caused such a melancholy tragedy.

Perhaps the best of all evidence, on the subject of the safety of the single system, is in the fact, that the Passengers' Insurance Company, know no difference of risk between the single and the double railway. In the insurance of life and property by all other companies, we find the very nicest differences of risk, and all the circumstances leading thereto, appreciated, tabulated, and charged to the insurer; but in the practice of the company referred to, there is no such difference known, or, if known, it has been held wholly unworthy of notice.

Costly signals are spoken of, as necessary for safety on single ways: I believe that the signal system is, at best, a most imperfect one, and much confusion and misunderstanding are evils constantly springing from it. That safety from collision (which embraces fifty per cent. of all the railway accidents) migh tbe almost wholly arrived at, by a more strict system of keeping time: the first requirement of which is, to have sufficient locomotive power for working the traffic on the line, and to have the means of keeping it in efficient working order; to have the time-tables so arranged as to meet every circumstance that can reasonably cause the retardation of trains; and hence, rather to increase the time allotted to the travelling of a given distance, than not to be strictly punctual. The public are irritable under the delay at stations and sidings, which occurs without good cause, beyond the advertised figures; but they cannot be dissatisfied, when there are strictly punctual arrivals and departures at the stations along the line, according to the tables; and they do not observe even a greater delay, in diminished velocity when the train is in motion, which more moderate speed, at certain places, might ensure the desired punctuality. Further, that such punctuality may be enforced, it would be wise to give the drivers good watches, and to establish good clocks at all the stations and sidings; to give premiums to the most deserving drivers; to abandon the system of fines and punishments; and not to keep, ON ANY TERMS, the careless or irregular. To carry out perfectly the system of accurate time-keeping, it may be necessary that the drivers be of a superior class to those which we constantly find in Ireland: good mechanics, sober, and intelligent, who thoroughly understand the course of the traffic which they have to meet and work with. Indeed it might be desirable, that each driver should have placed conspicuously before him on his engine, the trains which he has to meet in his run, and the positions in which he is to pass them.

Finally, on this section of the subject, I would say that, with the strict punctuality which should characterize all railway arrangements, and which is not too much to expect from the present state of mechanical science and skill—the caution and intelligence that should distinguish railway officials of every grade—guards and drivers as well as managers and engineers—the single is, in every respect, as safe as the double way.

Establish, then, for the working of the single system, telegraphic connexions between the sidings and stations on the line, by which, at every stopping place, intelligence may be had of the motion of the trains before and behind, and a degree of security will be attained, beyond which there would be nothing left to desire.

The second question in this inquiry may be put in the following words—"*Can a traffic as considerable as that on the best lines in Ireland be carried on single lines as well as on double lines?*"

In Professor Lane's papers on Railways in Holland and Belgium, there is sufficient matter, argumentative and statistical, to satisfy every unprejudiced mind upon the subject: the number of trains per day working safely and well over single lines—Irish, English, Prussian, German, and Belgian—being, in many instances, as great, and in some greater, than over our double Irish railways.

But for the purpose of considering this question practically, I shall take the case of the Great Southern and Western Railway of Ireland, where there is a double line throughout, with a large traffic, and consider the movement of the trains at present upon it, and see what arrangements would be necessary to work it with a single track.

The time table for this month (April, 1855) shows that the following trains are passing daily upon this line, amounting in all to seven trains each way per diem:—

UP TRAINS.				
1. Kilkenny to Dublin,	Speed,	23 miles	per hour,	including stoppages.
2. Limerick to Dublin,	,,	$23\frac{7}{9}$	,,	,,
3. Cork to Dublin,	,,	22	,,	,,
4. Do.	,,	25	,,	,,
5. Do.	,,	$23\frac{1}{2}$	,,	,,
6. Cork to Thurles,	,,	22	,,	,,
7. Cork to Dublin,	,,	$26\frac{1}{3}$	,,	,,

DOWN TRAINS.				
1. Thurles to Cork,	Speed,	20 miles	per hour,	including stoppages.
2. Dublin to Cork,	,,	22	,,	,,
3. Do.	,,	25	,,	,,
4. Do.	,,	$23\frac{1}{2}$	,,	,,
5. Dublin to Limerick,	,,	$23\frac{7}{9}$	,,	,,
6. Dublin to Kilkenny,	,,	23	,,	,,
7. Dublin to Cork,	,,	25	,,	,,

The intersections of the above trains occur in the manner and situations described underneath:—

1st up train meets the 2nd down train at Kildare, and the 3rd at Straffan.

2nd up train meets the 2nd down at Portarlington; 3rd between Newbridge and Kildare.

3rd up train meets 1st down at the Limerick Junction; 2nd between Roscrea and Templemore; 3rd between Maryborough and Mountrath; 4th at Straffan.

4th up train meets the 1st down between Mallow and Blarney; 2nd between Knocklong and Limerick Junction; 3rd at Limerick Junction; 4th between Maryborough and Mountrath; 5th at Hazlehatch.

5th up train meets 4th down at Limerick Junction; 5th at Roscrea; 7th at Kildare.

6th up train meets 5th at Goold's Cross.

7th up train meets 7th at Limerick Junction.

These intersections are 18 in number, but, from coincidence of position, the number of sidings necessary to allow these

trains to pass is only 12! Or, in other words, to work the passenger traffic of the Great Southern and Western Railway of Ireland *not more than twelve sidings would be necessary*, and of these twelve sidings one-half the number would be at stations as already existing! And this arrangement includes the accommodation of the branch traffic on the main line.

Now let it be granted that the goods' traffic will not require a greater amount of additional accommodation for the passage of its trains, and we shall have 24 sidings as necessary for the accommodation of the traffic of all descriptions on the 165 miles of line; and this is an excessive estimate of the amount of accommodation necessary for all purposes.

With regard to the length of these sidings, it may be stated that an excessive average for goods' trains will be 16 waggons, and the greatest would not exceed 40 waggons. The passenger trains will not amount to more than half that number of carriages. The length, therefore, absolutely necessary for each siding would be about 20 chains; but, for the purpose of giving ample room for stopping and starting, their length may be taken at half a mile each.

Thus, then, we have 24 sidings, each of the length of 40 chains—equal to 12 miles of line—add to which 4 miles of additional way for short sidings, necessary at junctions and in stations, and we have 16 miles, or 10 per cent. of double line necessary on the whole line from Dublin to Cork.

Referring to several lines in Ireland (the Dublin and Belfast Junction for example), it may be proved, that this 10 per cent. of siding, derived from the time tables of the Great Southern and Western, is in excess of what has been found sufficient to work as large a traffic.

Great stress has been laid, in the remarks upon Professor Lane's paper by the Engineer of the Midland Great Western Railway, upon the impossibility of providing, on single lines, for the "great increase of traffic at the races, and at the great

annual fairs of Ballinasloe and Mullingar;" and a very questionable principle has been advanced, viz., that "provision *in the construction* of a line should be made for the maximum and not for the ordinary amount of traffic in such cases."

In reply to this it must be admitted that provision should be made for the maximum amount of *profitable* traffic on all lines! But that it should be made by the doubling of a railway I deny! The obviously proper, and necessary arrangement to meet this difficulty, is the enlargement of the locomotive power and rolling stock upon the line; and most clearly, not by the doubling of the line. A constant amount of stock, capable of carrying a given amount of traffic, or to meet a contingency such as that mentioned, would be necessary, whether a railway had one track, two tracks, or ten tracks! and, in this respect, the Directory or Management of the Midland Great Western Railway failed to accommodate the traffic at the extraordinary time mentioned. Indeed, so notoriously inadequate were the locomotive power and carrying stock on that railway, at the time that these views were advanced, that the arrivals of the mails and ordinary trains were constantly delayed much beyond the time advertised.

It surely is an absurd proposition, that for the accommodation of the extraordinary traffic occurring only three or four days in the year, the whole length of a railway, of over an hundred miles in length, should be doubled!

The increased traffic in this case, is an increase *over a greater space of time* in the *same direction*—That is; in the mornings the extraordinary traffic to a fair or race-course is very great, but it is all in one direction, viz., toward the point of attraction! In the evening, the extraordinary traffic is all in the opposite direction, viz., returning from that point of attraction! Therefore, the prevailing streams of traffic would never come into collision! and hence the single line, without even an increase in the number of sidings, would answer all the requirements, as

well as if no such extraordinary traffic existed—the locomotive power and rolling stock being equal to the emergency!

It is a principle of railway economy, that certain branches of traffic may be carried at a loss, as in the preponderance of certain kinds of remunerating transport in one direction, over that in an opposite direction, where the haulage of empty vehicles may be saved, and something added to the total receipts by the adoption of a vanishing tariff. In cases of competition with steam-boats or other railways, or with a view to the development of a traffic which may at some future time bear a remunerating tariff. But, the principle of laying down additional lines of way, or of adding indefinitely to either the locomotive power or the carrying stock of a company, for the PERFECT accommodation of such transient traffic, cannot be admitted, except after the most grave consideration. Indeed, it should be a serious question with a directory, whether they should provide *at all* for such contingencies, beyond their ordinary resources of stock and power.

Mr. Hemans states, in his remarks on Professor Lane's paper, that the traffic (nine trains each way per diem) on the North Holland Railway might be shown to be less liable to difficulties in its carriage than the same amount of traffic on a single line elsewhere!

I confess my inability to understand how this is! Let us realize the density of the traffic on the North Holland Railway by a parallel case, in which we shall suppose our own principal towns in Ireland placed upon a line of equal length. Let Dublin be one of the termini; at 12 miles distant place Cork; at 34 miles place Limerick; at 50 miles, Waterford; at 60 miles, Londonderry; and let the other terminus, 75 miles distant, be Belfast. Moreover, let the country, in an industrial point of view, be superior to anything that poor Ireland can boast, and we shall have the parallel here of what the Amsterdam and Rotterdam is, as worked with a single line

of railway. Can anything be more convincing than this illustration? Can it be doubted that a railway with a traffic attached to it, carried at a speed of 30 miles per hour, flowing from what is equal to the concentration of *all* our centres of traffic, is sufficient for any requirements that can exist in Ireland.

I, therefore, dissent from the proposition that there can be any difference between the arrangements necessary to work nine trains each way over 70 miles of single line in Holland, and the same number of trains on the same length of line in Ireland, or any where else in the world. It is even more absurd than the fallacy of the fairs, and is wholly untenable.

The traffic between Belfast and Dublin, which is carried over the Ulster, Drogheda, and Junction Railways, has been as safely and surely carried over the 55 miles of single line, which the Junction occupies in the system, as on the remaining 50 miles of the Drogheda and Ulster Railways.

The following schedule will show the comparative densities of traffic on the double and single lines, as at present worked in Ireland:—

THROUGH TRAINS ON DOUBLE LINES IN IRELAND.	
On the Great Southern and Western Railway are	4 daily.
,, Midland Great Western Railway	5 ,,
,, Ulster Railway	5 ,,
,, Drogheda Railway	7 ,,
THROUGH TRAINS ON SINGLE LINES.	
On the Dublin and Belfast Junction are	5 daily.
,, Belfast and County Down Railway	5 ,,
,, Belfast and Ballymena Railway	5 ,,
,, Dundalk and Enniskillen	5 ,,
,, Dublin and Bray	9 ,,

Thus does it appear, that on our own Irish lines as great a traffic is accommodated as on our double lines. Proof this,

which puts us beyond the necessity of going to foreign countries to look for the evidence of the efficiency of the single system.

Finally, on the question of the *capacity* of the single way. When the traffic of a country more rich in minerals, agriculture, and manufactures than Ireland, and more dense in population than any other country in Europe, is carried over single lines safely and satisfactorily, it is conclusive general evidence that we have been either guilty of extravagance in the outlay on double lines, or wanting in the intelligence necessary to work the traffic safely and effectually over single lines. The former conclusion is unfortunately in keeping with our national character, public and private; and the latter is even more humiliating, but, I believe, less true than the former.

The difference of cost between the single and the double way is now to occupy our attention; and as the statements put forward on authority in Professor Lane's paper show a very wide discrepancy with the remarks which follow it, I shall try, from independent materials and resources, to arrive at a right conclusion on the subject.

It ought to be a sound proposition that railway works, the success of which is so much dependent upon their commercial character, should be limited by the rules of ordinary business enterprizes in the hands of private individuals, and should be limited in extent to suit the requirements of the generation in which they are executed, leaving their extension to those who come after, should that succeeding generation require the accommodation.

The trader or manufacturer who, at his outset in life, would erect or hire for his use stores, workshops, or warehouses of an extent equal to ten times his trade and capital, on the supposition that in twenty years he or his children might require such accommodation, would be properly accounted a lunatic. We know that it is the practice in all wise business

enterprizes to commence cautiously, and not to throw capital into a position where we may lose its use. Yet, notwithstanding this common-sense procedure in private affairs, the practice of Joint Stock Railway Companies has been sadly different. Engineers seldom holding scrip, and therefore indifferent to the financial position of the companies for which they worked, studying only the erection of magnificent works, through which they might extend their fame; and directors, in ignorance of their duties, conspired to spend in times past such sums of money upon railways, as nothing short of the fabled prosperity of the mineral and manufacturing districts of England could afford.

The Britannia tube is a specimen of this monstrous system of expenditure; in which instance, to raise the fame of one man, something like £400,000 more than was necessary, has been spent.

I do not know that two trains have never passed on this bridge; but I do know, and confidently assert, that it was not necessary, for even the traffic of the London and Holyhead Railway, to make a double line across the Strait.

It must be admitted, at the outset of the discussion as to cost, that a double line is in the abstract better than a single line; but that it is better on the principle elucidated in the remarks on Professor Lane's paper, I must beg leave wholly to deny.

Mr. Hemans, in his "Remarks" published in the Transactions, says, that "with a very confined capital it may be occasionally necessary to construct only single earth works." Where, let me ask, is the line in this country where the capital has not been confined? Shall I refer to the Government aid to the Galway Extension—to the transfer of nearly the entire stock of the Newry and Enniskillen to one individual at a nominal price—to the almost bankruptcy of the Derry and Coleraine—to the difficulty which the Ballymena,

Ballymoney, Coleraine, and Portrush Company experienced in getting a contractor—to the financial position of the Wicklow Railway, the consequences of which, at this moment, are notorious, but may not be mentioned—to the Dundalk and Enniskillen, supported in its credit by the wealth and public spirit of one noble earl—to the recent dividend of one per cent. on the Derry and Enniskillen preference shares, *which cannot be paid in money*—to the panic at the last half-yearly meeting of the Waterford and Tramore—or, finally, shall I refer to the unjust and general issue of preference shares everywhere? by which the poor man's stock is eaten up by the rich. In a word, from the quotation referred to at the head of this paragraph alone, it might be proved that on *every* occasion it would be wise and necessary to construct single works only. Let those remarks conclude with the words, "whenever the capital can be had it is much better to construct everything for a double way."

That is, independent of the nature of the country—independent of the traffic to be expected—independent of the number of passengers, and of the goods—wholly apart from whether the line will pay 10 per cent. or *no* per cent. upon the capital! Surely this is not reasonable.

If £750,000 make a railway of a given length (say 100 miles) which will do the same work as effectually and as safely as if a million were expended, why should I spend £250,000 for which I can get no return? This is the simple question, and one that it requires little skill or intelligence to understand or to answer.

Let us, then, see how this hypothesis applies. I shall take the case of a railway, such as the Great Southern and Western, in the magnitude of its works; and first, make an estimate of its cost per mile under the different circumstances of single and double tracks.

I have laid upon the table a Parliamentary section which

corresponds to the case before us, and on that section shall approximately estimate the cost of the double line (the items of which I shall try to keep unobjectionable), and afterwards (modifying the quantities and works) shall try to arrive at the cost of the single line on the same section. By these means I propose to get both the total cost of each and the difference between them; thus I shall have the saving in money and in per centage of work and expense.

The formation of the double line is assumed to be 30 feet, and for the single line 18 feet. The slopes are taken at 1½ to 1 throughout in both cases. I have calculated the quantity of earthwork for both formations, and can pledge myself to the accuracy of the quantities returned.

ESTIMATE OF THE COST OF 44 MILES OF DOUBLE LINE.

3,918,836 cubic yards of Earthwork, @ 1*s.*,	£195,946
Land, 528 acres, @ £70,	36,960
Fencing 44 miles, @ £130,	5,720
Over-road Bridges—15 @ £600,	9,000
River and Under-road Bridges—52 @ £600,	31,200
Public Road Level Crossings—18 @ £70,	1,260
Occupation Roads do., 26 @ £50,	1,300
Do. over Bridges—16 @ £240,	3,840
Do. under Bridges—19 @ £240,	4,570
Culverts, Large—47 @ £120,	5,640
Do. Small—50 @ £60,	3,000
Permanent Way (Barlow)—15,840 Tons, @ £10,	158,400
Ballasting 77,440 cubic yards, @ 2*s.* 6*d.*,	9,180
Stations—44 miles, @ £200,	8,800
Cost of Act and Engineering—44 miles, @ £500,	22,000
Rolling Stock, Locomotive Power, Machinery, Turn Tables, &c., } £1,000 per	44,000
	£540,816

The foregoing estimate is for *the double line, with all works doubled.*—£540,816 for 44 miles, is £12,300 per mile.

I shall now estimate the cost of the single line, with all the works single, by which I will show the absolute saving by the adoption of that system.

ESTIMATE OF THE COST OF 44 MILES OF SINGLE LINE.

3,321,100 cubic yards, @ 1*s.*,	£166,055
Land—10 acres ℔ mile, @ £70 ℔ acre,	30,800
Fences—44 miles, @ £130,	5,720
Public Road Over-Bridges, double—15 @ £600,	9,000
River and Public Road Bridges, under—52 @ £500,	26,000
Public Road Level Crossings, complete—18 @ £70,	1,260
Farm Road do., 26 @ £50,	1,300
Do. Over-Bridges, double,—16 @ £240,	3,840
Do. Under-Bridges, single—19 @ £200,	3,800
Culverts, Large, single—47 @ £80,	3,760
Do. Small, do. 50 @ £40,	2,000
Permanent Way (Barlow)—8,360 Tons, @ £10, including Points, Crossings, and Laying Rails,	83,600
Ballasting 42,592 cubic yards, @ 2*s.* 6*d.*,	5,310
Stations—44 miles, @ £200,	8,800
Cost of Act and Engineering,	22,000
Rolling Stock and Locomotive Power, Machinery for Shops, and Turn Tables,	44,000
	£417,245

The amount of this estimate, divided by the length, gives £9,480 as the cost of the single line. This shows a saving of £2,820 per mile between the double and the single line on the section before us, which would be the absolute difference between the cost of a line *in every respect single*, and a line *in every respect double*. However, as it is a well grounded opinion, that in most cases land should be taken and under-bridges also built for a double line, I shall add an estimate suited to that case.

ESTIMATE OF THE COST OF 44 MILES OF RAILWAY, WITH SINGLE TRACKS—LAND AND ALL BRIDGES DOUBLED.

Earthworks—3,321,100 cubic yards, @ 1*s.*,	£166,055
Land—12 acres ℔ mile, @ £70 ℔ acre,	36,960
Fences—44 miles, @ £130,	5,720
Over-Road Bridges—15 @ £600,	9,000
Under do. 52 @ £600,	31,200
Public Road Level Crossings—18 @ £70,	1,260
Farm Road do., 26 @ £50,	1,300
Do. Over-Bridges—16 @ £240,	3,840
Do. Under-Bridges—19 @ £240,	4,570
Culverts, Large—47 @ £120,	5,640
Do. Small—50 @ £60,	3,000
Permanent Way—8,360 Tons, @ £10, with Points, Crossings, and Laying,	83,600
Ballasting 42,592, @ 2*s.* 6*d.*,	5,310
Stations—miles 44—@ £200,	8,800
Cost of Act and Engineering, £500 ℔ mile,	22,000
Rolling Stock, Locomotive Power, Machinery, and Turn Tables, £1,000 ℔	44,000
	£432,255

The cost per mile, according to these Estimates, is as follows:—

Double Line—cost ℔ mile, ...	£12,300
Single Line, with Sidings only, and no provision for after doubling—cost ℔ mile, ...	9,480
Single Line with Land for Double Line, and all Bridges doubled—cost ℔ mile, ...	9,820

Showing a saving of £2,820 in the former case, and in the latter, £2,480.

The additional saving to be realized by limiting the purchase of land and the under-bridges to the actual requirements of the track being only £340 per mile, I am of opinion, considering the *possibility* of a necessity for after doubling, and its additional rates of cost, that this is not sufficient to warrant the adoption of the *strict* system; and shall, therefore, simplify this discussion by stating that I recommend that land be taken and all bridges built for the double line—and on the saving in works, under these circumstances, I rely.

There is another method of estimating the saving in the single way. Thus it may be stated incontrovertibly, that the single railway at least saves the following works and items of expense:—

First, $\frac{9}{10}$ of a core of Earthwork of 12 feet thick and 14 feet high=13,636 cubic yards per mile, @ 1*s.*, .	£681
Second, $\frac{9}{10}$ of half the cost of Permanent Way, . .	1,620
Third, $\frac{9}{10}$ of half the Ballasting of the Line, . .	94
	£2,395

This is a corroboration of the former estimates of saving, and is good proof of the correctness of the calculations.

Some time since, relying upon the importance of this subject, and fully expecting the co-operation of the profession, I made an attempt, by the issue of circulars and schedules, to get information amongst the engineers and contractors in Ireland

of the comparative cost of single and double works, but in more than half the cases I was unsuccessful.

However, from English engineers of position in this country, I met with courtesy and assistance, and I propose to quote their opinions, with regard to the saving, in very simple terms: the general practical savings in the different departments of cost being nearly the same as returned by all.

Thus it is agreed that, in average works which would occur in Ireland, $\frac{1}{5}$ is the saving in earthworks, and $\frac{9}{20}$ in permanent way and ballasting.

This would give —	Earthworks, saving $\frac{1}{5}$, ...	£890
,,	Permanent way and ballasting, $\frac{9}{20}$ saving, .	1,714
		£2,604

This would show, that in the opinion of persons competent to judge—of such men as Mr. Miller, of the Great Southern and Western, and of Professor Godwin, of King's College, Belfast, and the Ulster and other railways, that my estimate of saving is within the actual amount, and may be fully relied on as the net difference in average works.

If the I or other rail with timber bearings, were used, the saving might be shown to be still greater, from the natural decay of the timber in the road; which should, independent of all traffic, be renewed every twelve years. This would amount to £300 per mile, taken out of capital in the first instance; which sum, at interest, would be necessary to produce the cost of replacing the timber in the time mentioned.

This decay is, however, usually met by a sum taken out of revenue every year, and set apart for the purpose, and therefore the above additional saving might be said to be improperly taken into account; but, whether taken from capital in the first instance, or out of revenue in the last, it will have exactly the same effect on the value of the stock.

In the foregoing estimates, it will be observed that there are only two items which will vary with the character of the works, viz., the earthworks and the permanent way.

The latter is a quantity which does not admit of dispute, for it is always exactly half the double way, minus the length necessary for sidings; and the former may be almost demonstrated to every reasonable mind.

It has been already put forward, that the saving is equal to a core of earthwork, twelve feet in thickness, running through the whole length of the line. This is strictly true.

The difference in the cubic quantities of cuttings and embankments will, *in the slopes*, vary as the square of the height; but the difference in the areas of *cores* of different heights will be directly as those heights.

This latter proposition states the difference between the savings in works of different magnitude, as between the single and the double system: the slopes containing the same quantity in works of the same height, whether in the single or double line. Thus, if ten thousand cubic yards per mile are saved in the excavations of a line whose cuttings average 15 feet in height, twenty thousand cubic yards would be the saving in a line whose cuttings average 30 feet high.

I have found, by calculation, that the cuttings on the section before you average 14 feet in height. Now 20 feet in average height would very nearly double the earthworks of this line, and raise the cubic content to a maximum; and reduced to 8 feet in height would reduce the content to nearly one-third, which would be a minimum case of earthworks. In the former case the earthworks' saving would be $681 \times 2 =$ £1,362, and the whole saving on the mile $1{,}714 + 1{,}362 =$ £3,076. In the latter case the saving on earthworks would only be $\frac{681}{3} =$ £227; which, added to the cost of permanent way complete, gives $1{,}714 + 227 =$ £1,941, as the saving on the whole mile in minimum works, the average of the two

being £2,507. Thus it is seen that the whole range of difference between the earthworks averaging 30 feet deep, and averaging 8 feet deep is not above £1,133 per mile.

Now the estimate of saving already put forward as for average works is only variable within the limits up or down of half that amount, or £570. The whole range, therefore, of the difference in the value of stock arising out of maximum or minimum works, will be between $\frac{1}{12}$ and $\frac{1}{50}$; being correctly the proportion which that difference bears to the whole capital.

The iron in the permanent way is the main item of saving in the single railway. The great fluctuations in the price of this article, ranging from £8 to £16 per ton, make it impossible to reckon on a first saving in money; but taking the cost of laying the Barlow rail at £120 per mile, it will be seen that the price per ton, £10, set down in the estimate, only takes credit for the minimum saving in this department. The earthworks are treated in the same liberal manner in the estimate, 1s. per yard only being reckoned on, which is the minimum figure used for estimating the works of an entire line, and calculating on slopes of $1\frac{1}{2}$ to 1 throughout—a great portion of the work in such slopes being relied on as unnecessary in the execution, from the expected occurrence of rock excavation in the work, which reliance could not here exist, inasmuch as the saving is always *of a portion of the core of the earthworks*, and never affects the slopes.

Thus, in both items I have used figures which are below what I might assume as the saving due to the single railway against the double line.

However, even with these figures it has been shown that the saving in cost fully bears out the statements of Professor Lane, and the estimate long since published by the Railway Commissioners.

Recurring to the estimates the total cost of the mile of

railway is £12,300, and the average saving is £2,500; which is at the rate of 21 per cent. upon the cost! This sum may be stated to increase the dividends in this ratio, converting the 3 into $3\frac{2}{5}$ per cent.—the 4 nearly into a 5 per cent.—the 5 to $6\frac{1}{4}$ per cent per annum; and so increasing the dividends in the same proportion that the saving bears to the capital.

But the great importance of the saving of capital and the increased dividend is not altogether in the absolute value of either; but exists, in a great measure, in the healthier action which they carry with them—in the greater confidence given to the capitalist seeking investment—and in the consequent execution of additional works—in the increased employment of the engineer, the artisan, and the labourer—in the greater accommodation given to all mercantile and travelling classes of the community, and to the thousands of improvements inseparable from the more rapid extension of railways over the world!

ANNUAL GENERAL MEETING.

[Tuesday, October 16th, 1855.]

B. D. GIBBONS, Esq., In the Chair.

William Eaton Orr, Esq., C. E., Londonderry, candidate for admission into the Institute, was balloted for as a member, and duly elected.

Messrs. Bower and Dickenson were requested to act as scrutineers of the ballot for the election of the members of council, and other officers, for the ensuing session.

The annual report of the council on the proceedings of the Institution during the past session, having been read, was approved and ordered for circulation in the usual manner.

Mr. R. Mallet, member, then proceeded to explain the nature, peculiarities, mode of manufacture, and cost of his PATENT BUCKLED PLATES, and illustrated his observations by a reference to one of the plates, and to a series of drawings which exhibited a variety of the uses to which they were being applied at the present time, among which were mentioned for the floor of New Westminster Bridge, London—for fire proof floors of warehouses, &c., both simply and in combination with heating and ventilating contrivances, and for the Heligoland huts. In the course of his remarks, Mr. Mallet pointed out the advantages he believed the BUCKLED PLATES possessed over the corrugated iron sheets, and stated, in general terms, the theory of their strength.

In the discussion which ensued, Mr. Hemans, Mr. Gibbons, and other members joined, a very favourable opinion appearing to be entertained of the merits of the invention.

The ballot having been closed, the scrutineers reported that the following gentlemen were duly elected to fill the several offices for the ensuing session:—

President:

RICHARD GRIFFITH, Esq.

Vice-Presidents:

G. W. HEMANS, Esq., CHARLES VIGNOLES, Esq.,
M. B. MULLINS, Esq.

Council:

SAMUEL DOWNING,	WELLINGTON PURDON,
BARRY D. GIBBONS,	SAMPSON CARTER,
ROBERT MALLET,	JOHN NEVILLE,
R. HARDING,	JOHN HILL,
PARKE NEVILLE,	R. H. FRITH, Esqrs.

Secretary:

ALEXANDER TATE, Esq.

Auditors:

THOMAS BRAZILL, AND EDWARD RUSSELL, Esqrs.

[Tuesday, Nov. 13th, 1855.]

RICHARD GRIFFITH, Esq., LL.D., President, in the Chair.

Mr. S. Downing, member, exhibited and explained Professor Willis' apparatus for showing the greater deflection of girders under rapidly passing loads, than when acted upon by equal loads moving with small velocity, and satisfactorily manifested this result by the experiments made in the presence of the meeting.

Mr. Hemans, V.P., mentioned his opinion that the experiments just made ought not to be considered as conclusive as regards *compound* girders, and stated his belief that in practice the deflection is found to be less at high velocities—as an instance of which he referred to trials (lately made by him in company with Colonel Wynne, upon a bridge on the Longford branch of the Midland Great Western Railway, the span of which was 60 feet), which justify this opinion. He likewise stated he had found analogous results upon other occasions, and was aware that the opinions he entertained were likewise held by many eminent members of the profession.

It was remarked by Mr. Mallet that experiments of a similar character to those exhibited had been made upon a more extensive scale by Major James in the Portsmouth Dock-yard, in one of which the girder acted on was an ordinary railway bar, and that in every instance the results obtained were of a similar class to those exhibited.

The President observed, that in order to decide a question of so much interest and importance, it would be very desirable if an opportunity were obtained for having a series of experiments, carefully conducted under the auspices of the Institution, upon some suitable bridge on one of the lines of railway.

In consequence of this suggestion, Mr. Hemans volunteered to afford Mr. Downing the means of having such trials as might be necessary, made in conjunction with him.

[9th January, 1856.]

RICHARD GRIFFITH, Esq., President, in the Chair.

On the Physical Cause of the Increased Deflection of Girders or Bridges, exposed to the Transverse Strain of a rapidly passing Load.

By Robert Mallet, Esq., Member.

The fact of such increased deflection was established long since by the experiments of Captains James and Galton, R.E., and by Professor Willis, in connexion with the Commission of Inquiry as to the use of iron in railway structures; and the latter gentleman has founded some elaborate investigations upon the results, but of a character too abstruse to be of much practical application.

To M. Morin, the author of so many important investigations in physics, seems to belong the credit of having first pointed out, in a clear and distinct manner, the true cause of the phenomenon, and by a rigid discussion of the English experiments with theory, proved the entire trustworthiness of the latter, as well as the general correctness of his own views.

M. Morin has shown that in any beam or girder, or any bridge whatever, in which any deflection, however small, is produced by the transverse strain of a stationary load, at the centre or other point of its length, the same load will produce a still greater deflection, if transferred rapidly from end to end of the girder.

That this increase of deflection is due to centrifugal force, the path in space of the moving body being not in a right line, but in a curve concave towards the earth, and that the increase is greater as the original statical deflection is greater.

In the case of a body constrained to move in a circle, and

exposed to a tangential force, the centrifugal force f, or that in the normal, is

$$f = \frac{v^2}{\rho} \qquad (1)$$

ρ being the radius, substituting the height due to v^2,

$$f = \frac{2gh}{\rho} \qquad (2)$$

and in relation to the force of gravity, dividing both sides by g.

$$\frac{f}{g} = \frac{2h}{\rho}$$

For these we may substitute the expressions

$$f = \frac{m\,V^2}{\rho} = \frac{P}{g}\,\frac{V^2}{\rho} \qquad (3)$$

To connect this with the case of a moving load, constrained by a curved surface, of which any small portion may be viewed as a circle—the elastic curve not differing thus sensibly from it—we require the value of ρ for the static or fixed load, and the centrifugal force f in terms of it.

Poncelet has shown that in the case of any beam fixed at one end, and exposed to a strain perpendicular to its length at the other end.

$$\rho = \frac{\varepsilon\,I}{P\,C} \qquad (4)$$

ε being the coefficient of elasticity of the material—I the moment of inertia of the beam—P the load or strain—and C the length of the beam.

But from the usual equation, the deflection of a beam supported at both ends, and loaded in the middle, is

$$\phi = \tfrac{1}{3}\,\frac{P\,C^3}{\varepsilon\,I} \text{ from which we obtain } \frac{\varepsilon\,I}{P\,C} = \frac{C^2}{3\phi}$$

and substituting this in equation (4) we obtain the very simple expression for the radius of curvature due to the deflection,

$$\rho = \frac{C^2}{3\phi} \qquad (5),$$

which shows that whatever be the transverse section of the beam, the radius of elastic curvature is equal to the square of half its length, divided by three times the static deflection at the centre.

Now, as neglecting the weight of the beam, in relation to the passing load, the centrifugal force f is given by equation (3) $= \frac{P v^2}{g \rho}$; and substituting therein the value of ρ in equation (5). The expression for the force in the normal becomes

$$f = \frac{P v^2}{g \rho} = \frac{3 v^2}{g C^2} P \phi. \qquad (6)$$

But P = the static or stationary load: hence the total effort of the same load in passing along the curved line of the beam is

$$F = P + \frac{3 v^2}{g C^2} P \phi \qquad (7)$$

M. Morin applies this equation to the discussion of the experiments at Portsmouth of James and Galton, in five extensive tables; and as in some of these experiments the velocity of the passing load was extended until fracture of the cast iron beam took place, he shows, that *if* the true cause of the increased deflection be centrifugal force, then in all cases of fracture the value of F above must exceed that of R, the mean coefficient of rupture due to transverse strain on cast iron, which he takes at R = 32441000 kilo. (in accordance with the results of Mr. R. Stephenson's experiments), and on comparison he finds this actually to be the case, as well as a very strict coincidence between the experimental and calculated values of the other terms.

That the value of f is such as to be able easily to account for the facts, he illustrates by noticing that in some of the extreme velocities tried,

f is greater than 2 P,

or the centrifugal force more than twice the static load—and

hence the same beam was broken under loads smaller and smaller, as the velocity was increased.

The influence of centrifugal force, therefore, as affecting horizontal structures exposed to rolling loads at high velocities, is in all cases incontestable; for in all cases with any fixed load, however applied (even the weight of the structure itself), there must be some deflection.

The other conditions which affect the result, and sometimes appear to mask it, are, the weight or inertia of the girder itself, and its length in relation to v—*i e*, the time given for its bending under the rapidly passing load.

This increased bending or deflection takes place during the passing of the load, and the effort producing it takes time to be transmitted to the beam: hence, the point of maximum deflection occurs not at the centre, but beyond it, in advance, or in the direction of the passing load, and there it is that fracture occurs. When it occurs in several points, *apparently* at once, the beam is broken in several places in such rapid succession that its parts have not time given to separate at observable intervals; perhaps this effect of the shortening of the time of action with increase of velocity explains why it is that in the experiments made, the increment of deflection actually diminished in some cases, in place of increasing beyond a given limit of velocity.

The practical conclusions to be deduced are not unimportant. It follows, that the stiffer and the more elastic any railway girder or other bridge is, the less its deflection with its own weight, and any load at rest upon it, the smaller will be the disadvantage of the increased strain due to a load at high velocity passing over it.

That a high coefficient of elasticity, such as is obtained by the use of wrought iron, is of much more value than great weight in the structure. The effect of the inertia of motion due to the latter being to aggravate the evils produced by the

centrifugal force, although the primary effect of the inertia of rest must be to lessen the extent to which it can act in a given time of transit.

The equations (3), (6), and (7), show that the increased pressure of a given rolling load upon any girder bridge structure, increases as the square of the velocity, and inversely as the radius of curvature, so that the increased distress upon every structure along a line of way produced by the passage of an express train over that of a Parliamentary train of equal weight and length is in round numbers about as *four* to *one*.

Where the total load is applied uniformly over the whole length of the girder at once, as when it is loaded with engines or carriages, first at rest and then rapidly run over, the effect of the increased deflection is greatly masked. For, first, the static deflection due to a uniform load is to that of the same load applied at the centre only, as 5 : 8. Secondly, the normal force f acting always strictly in the direction of the radius ρ, when the girder is loaded all over at once, these forces at different points, in a certain degree, act against each other.

The views which have been thus enunciated, also fully clear up the apparently contradictory phenomenon (which as a fact seems pretty well confirmed) that the experience of skaters shows them they can most safely traverse thin and unsafe ice at high velocities. Here the beam or plate is loaded at one point, but it is supported from below at all points by a fluid, whose relative moment of inertia is enormous, and which requires a considerable time for its partial displacement. Moreover, the unloaded ice is an absolute plane. There is no static deflection due to its own weight; hence the only deflection *possible* is what can take place during the momentary passage of the skater; and if he passed in an indefinitely short time, there could be none at all.

Professor Willis in his preliminary dissertation (*Application of Iron to Railway Structures*), distinctly alludes to the pheno-

menon of increased flexure by rapidly passing loads, as one "in "which the effects in question are analogous to the centrifugal "action of bodies moving on curves," p. 187, and again alludes to this in pages 193, 212, and 213; but he nowhere very clearly enunciates the view that the question may be treated as a case of centrifugal force; nor attempts to do so.

He endeavours to find the trajectory of the curve over the flexible beam, from the differential equation of motion,

$$\frac{d^2 y^2}{d x^2} = \frac{g}{V^2} - \frac{g a^4}{V^2 S} \frac{y}{(2 a x - x^2)^2}$$

in which x and y are an ordinate and abscissa of the curve, a=the half length of beam, S=the central static deflection, and V=the velocity of rolling load.

This equation by certain artifices Mr. Stokes has succeeded in integrating—reducing the constants to a single one, which he calls β, and whose value is

$$\beta = \frac{g a^2}{4 V^2 S}$$

and in this way Mr. Stokes has given solutions for the problem in its two extreme cases, namely, where the mass of the bridge is neglected with respect to the rolling load, and where the mass of the load is neglected with respect to that of the bridge.

Neither case, however, occurs in practice, the motion of the bridge itself, and that of the rolling load, being always mixed up in the total effect produced on the structure. As the constant β increases in value, the increment of rolling deflection in the first extreme case diminishes; and in the second of the two cases this increment is measured by the fraction $\frac{25}{8 q}$ of S, the static deflection, the value of q being $=2\pi\frac{\tau}{P}$ in which P is the period of one complete oscillation of the bridge

from rest to rest, and τ the time in seconds that the rolling body takes to travel over the bridge.

Assuming, then, these fractions to represent the separate effect of the inertia of the bridge and of its load, and their sum the total effect; Professor Willis calculates the increment of static deflection due to each, in the case of certain of the experiments made, and finally calculates a table in which such increments are given for each, and for both conjointly, on the supposition that the weight of the rolling load and that of the bridge are equal, a supposition not very far from the fact in many cases.

This table, "rough and empirical," as the distinguished author of the paper is content to term it, is sufficient to show that in some cases of practice the phenomena cannot be neglected, for that when the value of β is $=5$ the minimum tabulated, the increment of total deflection may more than equal the whole static deflection, which in short and weak bridges traversed at high velocities might be very serious.

The treatment of the whole subject by Professor Willis is characterized by the clearness and ability that belong to all his works, but aiming at that perfection and generality that alone satisfies the desires of the mathematician, he has a good deal in his paper past the usual range of practical men, and by consequence his valuable investigations have been little studied by engineers, and seldom understood or fully mastered. This has greatly lessened the practical value of the results he has arrived at.

As the author of this paper found that doubts were expressed by some Members of the Institute at a former meeting, of the reality of the phenomena of increased deflection by rolling loads, and that the principles upon which the occurrence of such increased deflection in structures of *whatever* sort, exposed to transverse strain and moving loads, are proved to be inevitably necessary, did not appear generally known, he

deemed that a brief notice, in an elementary form, might n
be unacceptable.

NOTE.—The reader's attention is directed to the highly important mem
which has appeared recently in the 7th vol., 5th series, of the *Annales des Min*
upon this subject, by Mr. M. E. Phillips, Eng. des Mines, entitled "Calcul
la resistance des pontres droites, telles que les ponts les Rails de sous l'acti
d'une charge au movement."

[9th April, 1856.]

RICHARD GRIFFITH, Esq., President, in the Chair.

On the MAINTENANCE *of* MACADAMIZED ROADS. *Sequel to Paper read before the Institution of Civil Engineers of Ireland.*

By JOHN HILL, Member.

THE charge of the Commissioners of Public Works in Ireland, of the Roads in the Central District, together with other similar Roads, was determined by the 16th and 17th Vic., cap. 136, and ceased on the 1st July, 1854.

The system of repairs previously described, was continued in the central district, and the roads maintained in satisfactory condition up to the time the charge of the Commissioners ceased.

As it appears to me that the only possible objection to the general adoption of such a system for the maintenance of roads, is its apparent excessive expense, I have prepared a table of the cost and rate per perch of the roads from 1843 to 1853 inclusive, being the period they were under my superintendence.

During the years 1843 to 1845 the works of improvement and reconstruction were in progress; in 1847 the operations were affected by the general derangement consequent on the famine and relief works, but in the latter four years the expenditure settled to something near the average at which the roads could be maintained; if the same circumstances

continued, the cost would have somewhat diminished, as they were continually getting more substantial in the crust, and the workmen more skilful, in taking precautions for the repair of the weaker portions.

It is but fair to state that the roads were not situated, so as to give such a system of repairs a perfectly fair trial; from being in irregular detached pieces, they could not be divided into the most economical lengths for overseers, and were exceedingly inconvenient for superintendence; extending 70 miles in one direction, from Loophead to Kelly's Mills, near Portumna, and 60 miles in another, from the shore of Galway Bay to Robertstown, in the county of Limerick.

The roads in the county of Clare came into my charge as Surveyor under the Grand Jury Act, and preparatory to the cessation of the Commissioners' charge, I had them arranged in lengths to suit contractors of moderate capital, similar to the other county roads, made applications for presentments to the several Baronial Sessions, at rates 30 per cent. higher than the expenditure under the Board, which were granted and advertised for in the usual manner; but 68 miles, and those of least importance, were taken at these rates, leaving 86 miles without any arrangement for maintenance. At subsequent Sessions I was obliged to make application at much higher rates, to induce contractors to undertake their repair.

The Surveyors in the counties of Limerick and Galway made similar arrangements for the maintenance of the roads; in the latter county they have been contracted for at about the same rates at which they were previously maintained, but in Limerick and Clare the cost of maintenance is seriously increased.

I am of opinion that if continued under the same system as adopted by the Commissioners, an addition of 30 per cent. would more than cover the increased cost consequent on the rise in wages that has taken place in the district.

TABLE of EXPENDITURE for Labour and Materials, Maintaining the Roads of the Central Districts from 1843 to 1853 inclusive.

Denominations	Length in Miles	1843		1844		1845		1846		1847		1848		1849		1850		1851		1852		1853	
		Cost	Rate per Perch	Cost	Rate per Perch	Cost	Rate per Perch	Cost	Rate per Perch	Cost	Rate per Perch	Cost	Rate per Perch	Cost	Rate per Perch	Cost	Rate per Perch	Cost	Rate per Perch	Cost	Rate per Perch	Cost	Rate per Perch
		£	d.	£	d.	£	d.	£	d.	£	d.	£	d.	£	d.	£	d.	£	d.	£	d.	£	d.
1. Clare Repairs (West), . .	88	1,579	13½	2,706	23	2,294	19½	1,816	15½	2,719	23¼	1,593	13½	1,557	13¼	1,697	14½	1,844	15¾	1,590	13½	1,634	14
2. Limerick Road, . . .	17	236	10¼	373	15	424	18½	500	21¾	539	23¼	295	12¾	270	11¾	293	12¾	301	13	262	11½	287	12½
3. Clare Grant Repairs (East),	66	536	6	1,343	15¼	983	11	1,034	11¾	1,343	15¼	980	11	987	11¼	900	10¼	754	8½	732	8½	690	8
4. Galway Repairs, . . .	11½	151	10	417	27	118	9½	120	7¾	91	5¾	273	17¾	235	15	151	10	119	7¾	105	6¾	103	6¾
5. Galway Grant Repairs, .	37½	346	7	778	15½	334	6½	{260* 310}	6	{368* 489}	9¾	662	13¼	834	16½	554	11	448	9	489	9¾	425	8½
Total, . . .	220	2,848		5,617		4,153		4,040		5,549		3,803		3,883		3,595		3,466		3,178		3,139	

The sums marked * are for Bridges built those seasons.

The road between Limerick, Askeaton, and Robertstown, cost, on an average of six years, 12⅜d. per perch; it is now let on contracts for five years as follows:—

Barony of Pubble Brien,	1,081	perches,	2s. 8¼d.	per,	£146	7	8
„ Kenry,	2,243	„	1s. 8d.	„	186	18	4
„ Lower Connelloe,	1,743	„	1s. 7d.	„	137	19	9
„ Shanid,	453	„	0s. 6¾d.	„	12	14	9¾
Total, .	5,520	Average,	1s. 9d.		£484	0	6¾

being an increase of nearly 75 per cent.

In the county of Clare the contract on the roads is as follows:—

Ennis and Crusheen cost, under the Board,	1s. 3d.	Present cost,	1s. 6d.
Ennis and Kilrush—1st portion,	„ 1s. 1d.	„	1s. 6d.
„ 2nd portion,	„ 0s. 10d.	„	1s. 6d.
Kilrush and Mountrivers,	„ 1s. 4d.	„	1s. 8d.

The remaining roads of the Central District are mixed up with others in contracts, and divided so as to make the comparison difficult; the roads of little traffic are let at rates similar to the former cost, in general slightly increased, so that, as remarked in the former paper, the economy of the system is most apparent in the roads of heavy traffic.

Although but so short a period since the Commissioners' charge ceased, the condition of the roads under my own superintendence as County Surveyor has been seriously deteriorated, and I have reason to believe that a similar deterioration from their former order has taken place in the other counties.

When the improvements formerly detailed were completed, and the operations settled into a regular system of maintenance, the arrangements were, that each ganger was alone employed, during the summer, on his district of from four to six miles; additional workmen were added, beginning in October with one, and increasing as the winter set in to four or five in the beginning of December, which were generally continued till

the end of February, then gradually reduced as the weather improved, till the end of April, at which time I found, on an average of years, the extra workmen could be dispensed with. The overseers had authority to increase the number of labourers only in case of emergency; in some instances, from motives of economy, the increase of workmen in the commencement of winter was delayed too long, in every one of which I found the roads of heavy traffic got into such a state that no amount of exertion or expense, within reasonable limits, could restore them to a satisfactory condition, until the return of dry weather.

In the operations of cleaning and applying materials, the object endeavoured to be attained was of the nature of precautionary or preventive measures, more than of remedial, and I believe this to be the foundation of a good system of road maintenance. Such, it is obvious to me, cannot be attained under a system of small contracts, such as are enjoined under the present Grand Jury Laws in Ireland; if the motive of economy operated injuriously on those not directly interested in a pecuniary sense, how much more injuriously it must affect the operation of a contractor is very apparent.

On roads of much heavier traffic than any of those before alluded to, I am convinced that operations of the nature described, pursued vigorously, would effect greater improvement, and be attended with greater comparative economy; and it is to be regretted that on the roadways of many of the cities and large towns in Ireland, where the municipal laws do not trammel the operations in the same manner as the fiscal laws do in the counties, that more skilful and effectual measures are not adopted for their maintenance. I have observed the application of heavy coats of broken stones, of a large size, spread at a season, and applied in such a manner, as to be a serious obstacle to the traffic, and must of a necessity be nearly worn to atoms before consolidation took place,

furnishing the enormous quantity of mud and dust that afterwards is so slowly and ineffectually removed: even when materials are applied at a more suitable season, there is neither, what appears to me, proper preparation of the old surface, nor any attention paid to expedite the amalgamation of the old and new material, or other measures for the consolidation of the surface. The operations for cleaning seem to be inadequate and very defective. That such should be the case in the midst of the most intelligent and refined portions of the population, is very much to be regretted, and is naturally a subject of discontent and complaint.

ADDRESS OF G. W. HEMANS, ESQ.,

PRESIDENT,

TO THE

ORDINARY GENERAL MEETING,

DECEMBER 9TH, 1856.

GENTLEMEN,

I appear before you as President of this Institution with considerable diffidence, as I believe that the election might have fallen on more than one individual of our Society better suited to the post of honour. Connected, as I have been, for some years past with the construction and laying out of railways in different countries, my time has been so absorbed in the business of the hour, that participation in the more abstract investigation and studies incidental to our profession has been almost impossible; the attendance, even at scientific meetings, has been very little in my power, and for these reasons, I hope for yonr indulgent view of my performance of the duties you have chosen to appoint me to do.

Succeeding to men of so much eminence as your late Presidents, General Sir J. Burgoyne, General Sir Harry Jones, and Mr. Griffith, I cannot expect more than that it may be my good fortune not to see any deterioration of the position of this Society during my occupation of the chair. To these distinguished men, supported by the County Surveyors, the first existence of this Institution has been due, and to their continued support we have hitherto owed it, that the want of an adequate number of professional men resident in Dublin has not proved fatal to our Society. I may therefore, I trust, take this opportunity of expressing in the name of all, our sincere and cordial thanks and best wishes to our three late respected Presidents.

It has not been hitherto the custom to deliver an annual address from this chair, but we have precedents in other Societies where it is usual to pass in review such general objects of interest to Members as may be before the public, or likely to be brought forward. Some allusion to our private and professional interests as a Scientific Institution, and as Members of a wide spread, and not unimportant body of social labourers, may also be allowed. One object of all such Institutions as this, next to the inquiry after scientific truth, should be to cement firmly, by friendship and union, to elevate and dignify the profession of which its Members are composed.

It appears to me that, great and useful as the profession of a Civil Engineer may be, it is still much in want of organization, of recognized position among the higher professions, of definite unmistakeable claims or attainments, which, properly established, should be as much a passport to respect in social life, as the well-known insignia of other professions are supposed to give. I am well aware that this is perhaps a dangerous and delicate topic to touch upon, that many of our greatest and most successful men have almost by accident become

Engineers, and have been entirely, and sometimes irregularly, self-taught. But it is not for these powerful and shining lights that I speak; such minds will, in any position, break their way to respect and fame—I speak for the ordinary but large class of less distinguished men with good talents and industry, and in every way qualified for the practice of our profession, but who are sometimes embarrassed and injured by the crowding of unqualified candidates for the style and practice of Civil Engineers. To legislate on this subject might be, as some imagine, to impose fetters on free exertion and merit. I am not quite of that opinion, but I feel convinced that much might be done by Associations such as this, if sufficient efforts be made among ourselves, to maintain them at a high standard so as to command public respect. To be a recognized member of a professional Society, whose transactions give proof of ability, ought not to be without some weight in the competition of life, even though the law may forbid no one to enter the lists, whether so authorized or not.

I think I can observe in the sister country a growing tendency on the part of the public to treat with more respect professional opinions emanating from known Members of the Institution, as compared with those of other persons, and I believe that is precisely the kind of encouragement the profession most requires.

But if a connexion with a professional society is to be considered desirable for the marked and respected position it is supposed to give, two things become indispensable:—1st. The Society must be eminent itself. 2nd. The Candidates for Admission must be in some manner carefully tested before Election. It is of course quite possible for a large body of Engineers of considerable merit to exist and practice in a country like this, without any Society to support or encourage them, but if they do establish one at all, it is some reflection

on them, if it be in any way below a respectable standard. All that is needed is a sufficient number of monthly contributions in the shape of papers, to secure an interested audience, but in this essential point we are, I fear, deficient; and yet there is certainly no want of Engineering Works in the country, an accurate account of which would be both interesting and instructive. It would be easy to enumerate many such, and if any of our Members refrain from sending communications under the impression that they may not prove of sufficient interest, I would earnestly impress it on them, that such diffidence is quite misplaced. If a sufficient number of papers be sent in, the Council will be agreeably engaged in selecting the most worthy, and none are likely to be rejected which contain accurate practical records of any Engineering Work. In the English Institution, every Candidate for admission is obliged to communicate a paper—this practice has produced many good pages in the transactions, and I think it worthy of imitation here.

In referring to the works which have lately been carried on in this country, and with which I am best acquainted, it is difficult to avoid following the example of the distinguished President of the London Institution, in making the railways the principal theme of his address.

Other works of importance have been and are still in progress, under the guidance of some of our Members, such as those at Kingstown Harbour, and on extensive drainages, arterial and surface; but we are much in want of printed accounts of these works, and in point of outlay and variety of practice they afford less scope for remark.

Since the completion of the Shannon drainage and navigation, there has been no great bridge built in Ireland unless for railway purposes. I am therefore in a great measure restricted to subjects which must be already well known to most of us, although not perhaps collected in the manner I propose adopting.

The construction of railways in Ireland on a general scale may be said to have fairly commenced in 1840, when the Dublin and Drogheda line was in progress. It is true, that the Dublin and Kingstown, and the Ulster Railway were both then in existence, but the regular tide of railway works had not set in until the above mentioned date.

We now find at the close of last year a sum of, in round numbers, £14,165,000 sterling, raised and expended on Irish lines, representing a mileage of 987 or say 1,000 miles, and an average cost of £14,165 per mile, including all sources of outlay. At the same period the capital authorised to be raised was about £19,000,000, and as it is probable that all accounts for constructed lines were not settled at the close of the year, it may perhaps be safely estimated that the actual outlay on the 1,000 miles open at that date was about £15,000 per mile.

Of the whole length, 580 miles, or rather more than half, was then open as single line of way.

In England at the same date, there were open 6,218 miles of railway, of which 1,345 miles were single. The corresponding capital expended was, in round numbers £238,600,000= £38,300 per mile, or probably, on the same principle as above estimated for Irish lines, about £39,000 per mile. The English traffic has therefore apparently required 4-5ths of the length of their lines to be double, while in this country less than one-half of the total length as double line has been sufficient; nor is this to be wondered at, when we consider that the average traffic in England, is about £50 per mile per week, in Ireland about £20 per mile per week. But with the lesser traffic we have here a still smaller proportion of outlay, and the general result is so far favourable, that the average net income was in Ireland 4·03 per cent., in England 3·85 per cent. In England working expenses had borne the proportion of 48 per cent. to receipts, in Ireland only 41 per cent.

The moderate proportion of expenditure to gross receipts in this country would be surprising, when we consider the increased cost of coke in Ireland, were it not accounted for by the immunity we enjoy from the passenger tax, which is an impost amounting to about 7 per cent. on the receipts of English railways. From the above statements, which are principally derived from the useful and able returns of the Board of Trade, it will be seen that we have reason to be well satisfied with the results of our capital and labour expended on railways in Ireland. The works are not generally of the magnitude and grandeur which characterise many of the English lines, but nevertheless there are several points of considerable interest, and which have not, I regret to say, been brought before this Institution.

The Boyne Viaduct, so ably conducted by Mr. Barton, under Sir John Macneill. The Tunnel through the Slate Works, at Cork, and the Bridges over the Shannon and Lough Atalia, on the Midland Great Western Railway, are some of the many works quite worthy of a place in our records.

I have ordered copies of the drawings of the two latter, with short descriptions, to be prepared and presented to the Institution.

There is no doubt that Railway Engineering may to a great extent be looked upon as a speciality, and it would not be desirable to get into an exclusive routine of railway discussions, but I am of opinion, that considering the large capital in regular progress of expenditure, and that great variety of practice prevails in constructions of so much importance to the public, it would be highly desirable to invite and attract to us a few more of the Railway Engineers, and to endeavour to obtain from them the fruits of their experience and the communication of their proceedings.

There is one topic connected with this subject which I

cannot refrain from touching on, because I believe it to be of great importance to the progress of this country. I mean the system by which it is proposed to promote the construction of new lines in the less populous districts, under the stimulus of voluntary guarantees on the capital to be advanced; these consisting of rates-in-aid to be levied on the counties or baronies traversed, in order to secure a minimum dividend to the Shareholders in the undertaking. Nothing appears to me to be more legitimate and reasonable than such a proposition, provided the lines sought for be well laid out. A considerable agricultural district, not wealthy enough to show traffic sufficient to invite a speculative company, finds itself immeasurably thrown into the back ground by more fortunate neighbours, when competing to supply the great marts of export trade. They have no existing streams of public conveyances, no minerals, no manufactures to adorn a prospectus, but every farmer knows that with a railway to carry his cattle and grain to market, his gains will soon so much improve as to make a temporary payment to a company in lieu of all these things, a positive advantage to himself and his county, and if, with this conviction he voluntarily comes forward, and asks to have such a rate imposed, what hardship can there be in acceding to his request. Most foreign countries have advantageously adopted the guarantee system, and we ourselves are making vast use of it in India. Why should rates be more improper for the support of railways than for county roads, for the supply of gas, water, or for drainage? There seems to be but one difference, and that is the great alarm felt by some persons lest undue speculation should be encouraged by granting the principle of county rates. Suspicions are thrown out of a general conspiracy on the part of Contractors, Engineers, Solicitors, "*et hoc genus omne*" to entangle the whole country in a mesh of guaranteed lines by which they only are to profit. But will this cry bear investigation?

Have any Engineers or Solicitors in Ireland made large fortunes by railways? Of Contractors I do not speak; when coming forward as capitalists they have a right to make the most of their money, but there is little doubt in my mind that if the account could be squared, the country at large would be greatly the gainer by any profits Contractors are supposed to have made in Ireland.

I will now leave my professional speciality to turn to subjects of more general interest. More than one scientific and practical problem, of the highest moment, awaits solution in the coming year of 1857. These are such as we must all watch with attention, as on their success vast additions to the welfare of social life will depend.

The first in order is the Grand Atlantic Telegraph, now confidently brought before the public. Thanks to the liberality of the United States Government, an accurate line of minute continuous soundings has been carried across the ocean from the coast of Newfoundland to Valentia, the nearest point on the Irish coast, in the County of Kerry; Lieutenant Maury, of the United States Navy, the conductor of this investigation into what he terms "the physical geography of the sea," has published a very interesting account of his labours.

His discoveries establish "——— stretching away in a direct line from St. John's, Newfoundland, to the Bay of Valentia, on the Irish coast, a vast sub-oceanic plain, which is situated in the line of nearly absolute rest of the waters of the Atlantic, the bed of which has been shown by the specimens obtained on sounding, to consist throughout of the most minute microscopic shells, which, from their delicate organism, and the perfect state in which they are found, prove the utter absence of all motion in the water surrounding them." To use the words of the highest authority on the subject—"This plateau is not too deep for the cable to sink

"down and rest upon, and yet not so shallow that currents or "icebergs, or any abrading force can derange the wire after it "is once lodged upon it."

The soundings of the ocean along this plateau gradually increased from 1,000 fathoms to 2,070 fathoms, or about 2⅓ statute miles deep.

The ingenious apparatus by which these soundings were taken, has been drawn and described in the *Illustrated London News*, dated 13th September, 1856.

The principal feature is the contrivance by which the sinking lead, useless when it has attained the bottom, is there disengaged from the machine, carrying small tubes or quills which bring above water the materials composing the surface. England has already six sub-marine cables to the adjacent coasts. The cable which united Varna to Balaklava, in the Black Sea, was more than 350 miles in length, and was laid without difficulty; but being of a very light construction, it unfortunately broke after having been several months in use. The cable proposed to unite America and England will be extremely strong and pliable; it will contain seven strands of twisted wire, enclosed in gutta percha, and will be covered by a complete casing of iron armour. It is proposed to employ two steam ships in the submersion, each laden with half the cable, and that they shall proceed together to a point half-way between the two coasts, the total distance being 1,640 miles. The two ends of the cable having been carefully joined together, the vessels will proceed in opposite directions, one towards Ireland, the other towards Newfoundland, uncoiling the cable and exchanging signals through it from time to time as they proceed. By this method, each ship will have only half the whole distance to traverse, and the greatest depth and difficulty will be encountered first; hence, should any accident occur, it can only involve the loss of a few miles of cable, and the difficulties will diminish every hour. It is

expected that the operation will be completed in about eight days from the time of commencement.

The power of transmitting the electric current to such a distance, has been recently proved by experiments on 1,125 miles of similar wire laid on land. It is estimated that eight to ten words per minute may be sent, or 14,000 words per day. As it requires at present at least three weeks to communicate to and from America, the results of this grand operation, if successful, will be most striking.

The estimate for this magnificent project is only £350,000. It would be unjust to omit mention of the names of Lieutenant Maury, Professor Morse, Mr. Cyrus Field, Mr. J. Brett and Mr. Bright, some of the chief promoters of the project.

The next great experiment we shall hope to witness in the coming year, will be the starting of the splendid steamship, "The Great Eastern," now building at Blackwall by Mr. Scott Russell, under direction of Mr. Brunel. This immense vessel is built in two complete shells of wrought iron boiler plate, ¾ inch thick, an inner and an outer shell, united together in a cellular manner by webs of inch iron. She is 680 feet long, 83 feet beam; total depth, 60 feet; tonnage, 22,500, and for cargo, 18,000 tons; 2,000 H. P. nominal; diameter of paddles, 56 feet; diameter of screw, 24 feet. She will have 10 boilers, and 5 funnels, 7 masts; diameter of cylinders, (4 in number,) 74 inches. Anthracite coal is to be used. She is expected to go at the rate of 15 knots an hour, and to reach Australia in 33 days. Weight of iron used, 10,000 tons; will carry 12,000 persons. The mode proposed for launching the vessel is as follows:—

In constructing the foundation of the floor on which the ship is being built, provision is made at two points to ensure sufficient strength to bear the whole weight of the ship when completed. At these two points, when the launching has to be effected, two cradles will be introduced, and the entire

fabric will be lowered down gradually to low water mark, where, on the ensuing tide, the vessel will be floated off sideways. The estimated cost is over £1,000,000 sterling. This vessel will draw eight feet less water when light than when laden; and great care has been devoted to the designing of the paddle wheels to meet this difficulty.

The great impediment to the general use of such vessels must be the difficulty of getting harbours deep enough to hold them. The draft of the Great Eastern will be 28 feet. In the open sea the motion of such a huge bulk must be in the highest degree safe and equable, and even storms will be scarcely felt. The advantage of carrying all the fuel on board, and getting rid of the expense of sending coal thousands of miles to feeding stages, must be very great. Whatever be the commercial result, this ship cannot fail to be one of the wonders of the world, and its success ought to be ardently desired as an evidence of British enterprise.

We have, on a smaller scale, an experiment of more immediate interest about to be commenced; that of a line of steamers between Kingstown and Holyhead, to complete the sixty-three miles in little more than three hours. This of itself will be no mean achievement on our stormy channel.

I must now describe an invention as yet almost unknown to the public, but one of great merit, and if perfectly successful, destined to accomplish wonders. This is a tunnel cutting machine, invented by Captain Penrice of the Royal Engineers, who favoured me with an inspection of his designs on a recent occasion.

The machine consists of a species of steam battering-ram, or immense piston rod, at the head of which a powerful wrought-iron cross is fixed, consisting of 4, 8, 16, or 24 arms. These arms are completely studded with diamond-shaped steel points; and by an ingenious contrivance, at every blow on the face of the rock, a part of the revolution of the cross

is made; thus imitating the action of the boring tool in preparing for a blast.

The line of diamond-head chisels on each arm is thus kept continually cutting near an edge of rock, which is much more advantageous than a blow in the centre of a solid. The diameter of the excavation made is such as to include the whole of the machinery, which is on a wheel truck lying on rails, and progressively follows its excavator. The progress is something like that of the Teredo Navalis, which is supposed to bore, with its horny head, a hole large enough for the body to follow. The difficulty with a machine of this nature is, to temper the blow to the hardness of the rock which is to be cut, until the steel points will bear the re-action; accordingly this is very cleverly done in the machine by an arrangement similar to that of the steam hammer of Mr. Nasmyth, and in very hard rock, a speed of 200 blows to a minute, with a very short stroke, can be given. Ventilation is very well managed by the action of the waste steam, which is driven into a wooden conduit pipe, causing a strong current at the eduction near the mouth of the tunnel, and a consequent vacuum and return current within.

The cylinder is so managed as to keep a constant steam cushion behind the return movement of the piston, which movement is thus effected.—On the forward blow the heavy mass is stopped by, and a recoil takes place from, the blow on the rock; a differential pressure is then brought to bear on the reverse face of the piston, by means of a projecting ring giving an annular area for the backward stroke, in opposition to the circular area of the forward stroke. The moving mass is thus, to a certain extent, balanced between two steam cushions, the blow on the rock being the only jar. The experimental machine was made with a ram 5 feet in diameter, and it cut its way in sandstone, at Newcastle, at the rate of 20 inches per hour, to a length of 80 feet, when it became

clogged for want of proper arrangements to remove the chippings. This is now proposed to be done by means of something like a dredging ladder, which will cast back the material under the wheels of the engine, whence it can be taken away on trucks. As a proof of the importance attached to this invention by practical men, I may mention, that Mr. Brassey is setting one of them to work at the difficult tunnel called the Hunenstein, through the Jura Mountains, where he has been entirely stopped by water at one end, and has no means of getting a drift to carry it off within the time allowed for completing the work. The directors of the Worcester and Hereford Railway are going to adopt it to cut a tunnel of 13 feet diameter, in one operation, which, with the bottom levelled, is wide enough for a single line. The tunnel will run through the Malvern Hills; and as the material is Sienite, the machine will be severely tested. The ram in this case will have 24 arms, and will, it is expected, weigh about 20 tons. The very moderate sum of £10 per yard was allowed as the cost of executing this tunnel in the ordinary way, and the Company and inventor are to divide the saving, which the latter estimates at £3 to £4 per yard at the least. If this result be obtained, in addition to greatly increased speed of execution, this machine will effect a great revolution in railway works, and will make tunnels much cheaper than rock cuttings. Shafts will be scarcely necessary with this apparatus. It was intended to use it in sapping at Sebastopol, but the town fell before the machine could be made.

While on the subject of inventions, Bessemer's process for the treatment of iron by combustion of atmospheric air, must be mentioned as one, the progress of which is exciting great interest as well as controversy. The economical use of the idea will be one point on which its success or otherwise will greatly depend.

The above are some of the leading subjects which occur to

me as matters of interest to us in the coming year. It would be impossible to attempt complete enumeration of great works either just completed or in progress in England, and on the continent. There is the Roquefavour Aqueduct, 200 feet high, in France; the Semmering Railway over the Alps in Austria, with gigantic works and gradients of unexampled steepness; Mr. Brunel's Wrought Iron Bridge at Saltash—consisting, besides several smaller ones, of two openings, each 455 feet span—the girders being of wrought iron, and 50 feet deep—the centre pier on which they rest is built within a wrought iron cylinder, 37 feet in diameter, and weighing 300 tons, sunk to the rock in the bed of the river—the foundation is 88 feet below high water mark—the roadway will be 100 feet above high water mark—weight of wrought iron, 2,650 tons—total estimated cost, £162,000; Messrs. Gordon and Liddell's Crumlin Viaduct in Wales, on cast iron pillars 200 feet high; the Victoria Tubular Bridge, 9,000 feet long, in Canada; the Railway Suspension Bridge, 800 feet in one span, at the Falls of Niagara—all these are works worthy of the most attentive study, and reflecting great credit on their conductors. In Ireland, there is just approaching completion, an exceedingly well executed and fine work—the New Graving Dock at Ringsend. The masonry is of first-rate quality, the designs appear to be most carefully and ably made, and as the Engineer is one of our Members, we shall hope for a description of the progress of the work, and of the difficulties surmounted, which I believe were great. The steam pile-driving machine was extensively used, and a record of its merits as compared with the ordinary mode would be most interesting.

A very interesting and difficult bridge at Londonderry, where a Railway and Public Road are to be carried together over an arm of the sea, on a stratum, consisting of mere alluvial deposit to a great depth, will probably be commenced

next year, and as the profession has been invited to send in competition designs, it is to be hoped that an Irish Engineer may have the good fortune to be successful, and that a careful record of its progress will some day reach us here.

I have now to conclude this address by expressing my sense of the great compliment paid to me, by my election as President of this Institution; my hope is that, during my occupation of the chair, we may succeed in keeping up an interest in our meetings and transactions, and that good feeling and harmony may prevail at all our discussions, so that our Society may really achieve its proper objects in the promotion of practical science, and in establishing and placing on the best footing the profession of "a Civil Engineer."

[10th March, 1857.]

ROBERT MALLET, Esq., Vice-President, in the Chair.

The MONSTER CONTRACT SYSTEM; *its* INFLUENCE *on the* COST *of* WORKS, *and the* POSITION *of the* ENGINEER; by JOHN BOWER, Esq., Member.

IN a paper on the subject of single, compared with double railways, read by me in this Institute, I took occasion to refer to "The Monster Contract System," as being one of the causes of the increased cost of works; but, as it was the opinion of Council that the subject of the paper did not legitimately call for the discussion thus introduced, I consented to its withdrawal from the paper, as prepared for publication—not that I considered it foreign to the subject, but under the determination to discuss the question independently at a future time.

I now beg to redeem the pledge then given, and in doing so I shall consider the system in the twofold aspect of its *influence upon the cost of works, and its effects upon the position and character of the Engineer and his profession.*

That the cost of works is enhanced to an alarming extent by the "Monster Contract System," will be generally admitted; but as there is an all powerful class of men, (the foundation of whose wealth has been that very evil) the proposition no doubt will be disputed, and many ingenious ways will be taken to explain away the differences which exist; but the stubborn prices registered in deeds of contract (the memorials of our dear bought experience) remain unaltered, and enable us to contrast the cost of each description of work as executed by railway contractors, with the cost of that kind of work executed under different circumstances of contract—to weigh such explanations, and to come to a just conclusion upon the subject.

I have taken some pains to collect schedules of prices of railway works in this kingdom, as well as those of other works executed during the same periods of time, for the purpose of contrasting them with each other, but after great delay and disappointment I have been forced to abandon my expectations, and to proceed upon the small collection of schedules which the kindness and courtesy of a few friends have placed at my disposal.

Copies of these are now added for reference, by way of an appendix, but I shall not inflict them upon this meeting.

I shall, however, take leave to quote from them a few of the principal items of cost, and compare them with similar items in other contracts.

ABSTRACT OF SCHEDULES OF PRICES OF RAILWAY WORK.

—	Ashlar	Rock	Earth	Rubble Masonry	Box and Ballast	Laying	Puddle	Fencing, per Yd. Lineal		Culverts	Brickwork	Timber	Broken Stone for Road Metalling	Soiling Slopes	Date of Contract	Observations
								Wall	Ditch							
		s. d.	s. d.	s. d.	s. d.	s. d.		s. d.	s. d.	s.	s.	s. d.	s. d.	s. d.		
Dundalk and Enniskillen,	-	2 2	0 11	15s. hammered 8s. plain	1 6	1 6	-	1 6	-	20	18	4 0	-	-	1846	
Do., do.,	-	2 6	1 0	8 4	-	-	-	-	-	-	-	4 0	-	-	1852	
Belfast and Ballymena,	-	-	1 1	7 6	7 6	2 3	-	-	1 0	20	32–40	4 6	7 6	-	1845	Hammer dressing, 4s.; pick dressing, 6s., extra per yard super.
Ulster Railway, 1st,	-	-	0 6	-	0 9	-	-	-	0 7½	10	16	-	-	-	1837–38	
Belfast and County Down,	-	2 6	0 10	9 6	1 9	-	-	3 6	0 9½	-	-	-	-	-	1856	
Newry and Enniskillen Railway,	-	-	0 9	8 0	1 6	1 0	-	-	-	22	-	-	-	-	1856	Prices in tenders.
Derry and Coleraine,	-	-	0 9	14 0	1 6	0 10	-	-	-	-	21	4 0	-	-	-	
Killarney Junction,	-	2 0	0 8	-	1 3	1 6	-	-	1 0	21	-	-	-	1	1852	
Limerick and Ennis,	-	2 4	0 10	8 6	1 6	2 0	-	-	1 2	16	-	-	-	-	1856	
Dublin and Wicklow,	-	2 6	1 2	10s.–15s.	-	-	-	7s.–8 6	2 0	-	-	-	9 0	0 3	-	
Ulster Railway Extension,	-	2 0	0 9	7 0	-	-	-	-	0 10	-	20 x 26 c	-	-	-	1856	

ABSTRACT OF SCHEDULES OF PRICES OF COUNTY AND OTHER WORK.

—	Ashlar	Rock	Earth	Rubble Masonry	Box and Ballast	Laying	Puddle	Fencing, per Yd. Lin. Wall	Fencing, per Yd. Lin. Ditch	Culverts	Brickwork	Timber	Broken Stone for Road Metalling	Soiling Slopes	Date of Contract	Observations
		s. d.	s. d.	s. d.			s. d.	s. d.	s. d.	s. d.	s. d.	s. d.				
Strangford Road, County Down,	–	–	0 6½	6 8	–	–	–	–	0 3	6 8	–	–	–	–	1841	
Waterford County,	–	2 0	0 7	7 6	–	–	–	–	0 8	–	–	3 6	–	–	1856	
Fermanagh County,	–	–	0 6½	7 0	–	–	–	2 3	0 6	–	–	1 7	–	–	1856	Home grown timber.
Clare County,	–	1 6	0 6	7 0	–	–	–	–	0 3¾	–	–	3 0	–	–	–	
Armagh County,	–	1 9	0 6	6 6	–	–	–	2 0	0 3¾	–	–	3 0	–	–	1856	
Antrim County,	–	2 0	0 6	8 0	–	–	–	1 6	–	–	–	3 1	–	–	1856	
Ulster Canal,	–	–	0 10	10 0	–	–	–	–	–	–	–	–	–	–	1836	
Belfast Water Works,	–	–	0 6¾	6 8	–	–	0 11½	–	0 6½	–	–	–	–	–	1841	Prices in Lynn's tender.
Belfast Bridge,	–	–	–	8 0	–	–	2 0	–	–	–	13 6	3 6	–	–	1840	
Ban Reservoirs	–	–	0 9	–	–	–	–	–	–	–	–	–	–	–	1837	

From these figures it will appear that the average cost of earth excavations in railway work executed in this country may be taken to be 10d., whereas the average cost per cubic yard is, on county road contracts, 6¼d.

This difference is great, and in itself would form an immense saving upon the cost of Railways if the earth excavations in them could be executed for 6¼d. per cubic yard. To this, however, must be added the sum due to the additional average lead which always has to be encountered. The average lead on public roads of the best construction being not more than one third of that in ordinary Irish railways. The former may be taken at 300 yards, and the latter at 900 yards.

Taking Sir John Macneill's estimate of the cost of haulage per cubic yard, to be correct, (see "Tables for Calculation of Earth Work") we arrive at the following figures :—

Total cost of one yard of excavation, as per average of Schedules of County work, ...	6¼d.
Deduct cost of haulage for 300 yards, . . .	2¾d.
Cost of getting, filling, and teaming, . . .	3½d.
Add to this the cost of hauling 900 yards, . . .	4¾d.
Per cubic yard, ...	8¼d.

This is the fair value of one yard of excavations with the half mile lead, and this is the cost at which railway excavations in earth should be made under the circumstances stated.

In rock excavations the difference is much greater. Thus, the common price per cubic yard in a slate country (Cork, Dublin, Monaghan, &c.) has been from 2s. to 2s. 6d., and the price for the same work on common roads is from 1s. to 1s. 6d. The mean of the latter two being about the county contract average price. Making the addition to the latter for difference of lead, it would give 1s. 7¼d. as the average price at which excavations in rock on railway works should be executed in this country. This would give a saving of 7¾d. per cubic yard in rock excavations.

The monster railway contractor will no doubt say, in reply to this, that there are so many circumstances of difference between works executed under railway companies and grand juries which influence the prices that they cannot be compared. True there are such differences. The monster contractor supplies himself with plant upon a grand scale; his horses are of the largest and sleekest description; they are wonderfully trained, and a certain number of them are calculated to do the minimum quantity of work in a given time. These go in tandem, or unicorn, or two of them abreast, and with one or two drivers, and thus yoked, in a well-appointed waggon, often do as much work per diem as one strong and wiry Irish horse and cart. But let it be admitted that contractors' plant and stock are subjects of additional expense beyond what is necessary to execute county contracts. Inquire then what is the value of the necessary stock per mile, and give the contractor a fair sum per cent. for that capital invested in his trade.

The stock necessary to execute road contracts is, say £250, per mile. The stock necessary to enter efficiently and vigorously into a railway contract is, say £750 per mile. Here there is a capital sum of £500 per mile of clear difference against railway contracts, compared with contracts for public roads. The wear and tear of this stock may be taken at ten per cent.; this gives the sum of £50 per mile per annum as the amount which the contractor has to replace in his capital out of his employments, over and above what he would have on road contracts. Now, a low average quantity of excavation in railway works in this kingdom is about 30,000 cubic yards per mile; therefore $\frac{£100}{30000}=\frac{2}{3}$d. In other contracts in Ireland this sum would be less than a farthing per cubic yard, supposing it to be put to the debit of the excavation above. The average difference (allowing a reduction on account of the amount of excavation on road contracts, as between roads and

railways) is (by this calculation) ¼d. per cubic yard, which raises the price to 8½d. per yard for earth excavation. It is worthy of remark, however, that in all railway estimates, a large sum (at least five per cent.) is placed to the debit of plant, which practice should allow the calculation to be cleared of this ¼d. However, I shall let it stand, with the remark that the additional outlay on good tools, rails, and machinery, gives increased facilities for working, which in themselves more than counterbalance the outlay.

Railway works also, from their having lower gradients, have deeper cuttings, and from this cause also comes greater facility in the execution. The deeper the face, the easier the work, and the greater the profit to the contractor. Again, in all railway contracts entered into honestly, the contractor is paid monthly, or in bi-monthly instalments, whereas the road contractor must wait (except where the contract is very large, and he is paid by instalments) for periods averaging six months, from assizes to assizes, or perhaps for a year, or two years, till the contract is completed to the satisfaction of the engineer.

Thirty thousand cubic yards of excavation at 1½d. per yard is £187 10s. This is the sum per mile in light works over and above the fair price, (making all allowances) which the monster contractor receives in the department of earth excavations alone. I shall leave, till a later period in this paper, comparisons of railway prices amongst themselves, that I may more closely follow out the comparison of a few of the leading prices as between railway and road contracts.

The masonry of the contract is the next important item to the excavations, and in this also, will be seen material differences in similar descriptions of work.

The average price of rubble masonry per cubic yard, in the schedule which I have compiled, is above 9s. The road contract price per cubic yard is, on an average, about 7s.

This is the price inclusive of footings, abutments, wings,

spandrils, and backing; now, there is doubtless in railway masonry an additional price allowable for wider spans and better centering, but that there is a sounder description of work necessary than that which is executed in well-managed counties I deny. The allowance for additional centering and heavier material would not exceed 9d. per cubic yard, and even this may be too liberal, inasmuch as with heavier work come greater dimensions, which produce with the same area of face more solid measurement.

There is no reason that I know of, why a stone bridge of any given dimensions should cost more for a railway than for a mail-coach road, and there is no necessity, if there be honesty and fair dealing between a company and a contractor, that any man should receive for his work more than its fair value.

The average quantity of rubble masonry in bridges and retaining walls on ordinary railway contracts in this country is about 800 cubic yards per mile. The saving on this item, if county prices were adopted, (making all fair allowances) would therefore be at the rate of £50 per mile, statute.

The price of culverts belongs to this department. The average sum paid in railway contracts for culverts of from three to six feet diameter is about 20s. per foot of diameter per yard, lineal or cubic. I have no means of making a comparison with county contract prices in this item of cost; but may observe, that the cost of the work, in the hands of a small contractor, would not exceed 10s. per cubic yard, which, at 60 yards, the average quantity, would amount to £150 per mile.

In ashlar masonry executed in strings, quoins, coping rings, newels, &c., the difference between the county and the railway contract prices is about 6d. per foot for plain work; the former average being 1s. 6d., and the latter 2s. The saving on this item being, on about 1,200 feet, equal to £30 per mile. It

may not be out of place here to observe that this ornamental work, which costs 54s. per cubic yard, might be omitted altogether, and ordinary hammered stone substituted, at about half the cost, and without injury to the stable character of the masonry.

In the price of all timber used in piling, or in structures above ground, there is paid to railway contractors an average rate of 4s. 3d. per cubic foot; 3s. being about the average price paid in county contracts. There is therefore a saving of 1s. 3d. per foot available in this item. In certain contracts, it is true, timber is little used in permanent structures, but it is always an important article in the schedule of prices, and the average quantity on Irish contracts is somewhere about 700 feet per mile; which, taken at 1s. 3d. per foot, amounts to £43 15s.

One more instance, and I have done with these comparisons. Fences of earth are executed in railway works at the average cost of 1s. per yard lineal, while in county contracts their price is about five pence; and in many localities little more than half that amount is paid for them. The mile of railway requires about 4000 yards of same description of fence, and throwing out of the scale the greater saving to be effected in the article of stone walls, and allowing earth fencing to rule the estimate, the amount of saving would be £116 per mile.

There is a system in railway contracts of charging for road metalling in alterations, deviations, and approaches, per superficial yard, without reference to its *depth*, which is thus left to the liberality of the contractor. In the Wicklow railway contract the price was 1s. 6d. per superficial yard. This is about the value of a ton of the material used—the quantity expended being about 4 cwts. I do not calculate the saving in this item, as I have not sufficient data at hand, but content myself with a notice of this matter, with a view to its correction. I have thus drawn your attention to the leading differences

between the prices of the work on railway and on road contracts, and I have now to pass to the differences existing between *similar* works in *similar* contracts executed at *different* times, (*i. e.*) in railway contracts of the past and the present time.

In the year 1837, or thereabouts, the Ulster railway contracts, No. 1 and No. 2, comprising the section of the line from Belfast to Lisburn, were let to an Englishman, who had then been engaged for more than twenty years in the pursuit of his business in this country.

He was a builder by trade, and a man (though of the old school) who knew well the value and importance of the work.

The cubic yard of earth work in his schedule of prices cost 6½d. This was his own price, as he had no competitors of note, and I have his own authority for saying that he did not lose by it.

It is worthy of note here, that this contractor had to supply himself with plant, specially for this work; which plant, moreover, he had no opportunity of applying to similar work subsequently, as he soon afterwards retired from business.

The contract executed prior to these was the Dublin and Kingstown Railway; of these prices I have no note, nor is it of much importance, as the circumstances of all the works there differ considerably from those of most other works in Ireland.

This work, however, introduced to this country a man who, though a true milesian, had secured the benefit of an English education; it is not, therefore, astonishing that he should seek to introduce English prices into Irish works, considering that all the materials of construction, as well as the labour of the head and hand, were to be procured in this country at so much a lower sum than in the land which he had learned in and left. Irish inexperience and an English engineer made the task easy, and his sagacity and worldly wisdom were triumphant!

That contractor, about the time that the Ulster Railway con-

tracts above-mentioned were in force (and with similar assistance) secured a contract in Ulster, viz., the Bann Reservoir Works, in which the price of earth work was 9d. per cubic yard, which earth-work consisted principally of embankments made up from side cuttings within the reach of an ordinary barrow-run—a price, considering the difference in lead, somewhere about double that on the Ulster Railway contracts referred to.

The contracts between Lisburn and Portadown, which followed, were let upon the English system, and the great portion of the work was done by sub-contractors, who themselves gained both wealth and character by even their minor portion in the transaction,—the lion's share of the profits being held by their chief. This portion of the work was opened in 1842, and extended, in the hands of the same contractor, to Armagh, and was ready for traffic in 1848. Three years prior to the completion of this last contract, the Belfast and Ballymena Act was obtained, and the same year (1848) saw its completion.

This was the next great work opened in Ireland, and to the prices on that contract I wish particularly to refer. The price per cubic yard, with 25 yards "run" is in the schedule 6d., and for each additional "run" of 25 yards, 1d. per yard. That is, for every distance exceeding 425, and not exceeding 439 yards, the price to be paid to the contractor was solemnly agreed to be 1s. 11d. per cubic yard, for "gravel, till, or clay excavation."

	per mile	per yard
The earth-work prices in the schelule for the average lead given is - - - - - -	—	1s. 1d,
Pitching and ballasting single line - - -	£340 0s. 0d.	3s. 10d.
Boxing - - - - - - - - -	330 0s. 0d.	3s. 9d.
Laying of permanent way - - - -	312 0s. 0d.	2s. 3d,
Brick work - - - - - - - -	—	32s to 40s,
Fencing - - - - - - - -	—	1s. 0d,
Maintaining of way - - - - - -	145 10s. 0d,	—

Some of the items in this schedule are startling, and some admit of explanation. Let it be fairly given :—

The "pitching" I find described in the specification as placed under the whole of the permanent way to a depth of 8 inches, in the same manner as that used in foundations of public roads. The value of this would be about 3s. per cubic yard, while three-fourths of a cubic yard, per yard lineal, would amount to 2s. 3d. per lineal, or to £198 per mile of single railway. Deduct these figures from the sum per yard and mile for pitching, ballasting, and boxing, and the remainder is 5s. 4d. per lineal yard, or about £469 per mile for the boxing and ballasting alone. This sum, calculated at seven inches depth of ballast and six inches of boxing, would give 2,371 cubic yards, or about 4s. per cubic yard—a price more than double its value to the company. The price in the schedule for the laying of the permanent way is equal to that of a double line, more than double the price now charged by the permanent way company—a clear gain of £107 per mile over the fair marketable value of the work going into the pocket of the contractor.

Until the year 1847 no rise in the price of labour had occurred, and, wanting such an event, I am unable to account for the difference pointed out between the two first Ulster contracts and the Belfast and Ballymena prices.

From 1848, the time of completion of the Ballymena Railway, to the present time, there has been a steady increase in the price of labour, and from this circumstance we should reasonably expect to observe an equally steady rise in the cost of railways as executed by contract; yet the very contrary has been the case, and we find the same contractor who made the Ballymena line is now in the actual execution of a contract in the same province at vastly reduced prices. The Ulster Extension Railway schedule has the following items :—

	Ulster Extension.	Belfast and Ballymena.
Earth Work, . .	9d. per cube yard	1s. 1d.
Masonry, . . .	7s. do.	7s., & 5s. extra for face.
Fencing, . . .	10d. per yard lineal,	1s.
Brick-work, . .	20s. in mortar, 26s. in cement,	32s. to 42s.
Maintaining, . .	£90,	£145 10s.

In these early times of railways, the Londonderry and Enniskillen contract, No. 1, (from Derry to Strabane) revealed to some extent the magnitude of the profits realized. In this case it is notorious that the contractor had more than twice the fair value of the work.

The latter contracts upon this line, though made at very reduced prices still admitted of sub-contractors being employed who realized good profits beyond the sum of £1,000 per mile, which the chief reserved as his profit in the first instance.

The sub-contractor is, compared with landlordism, a sort of middleman by whose agency the principal acquires his gains without the trouble of superintendence or collection, who, thrown into a middle position, where profits were never calculated in the engineer's estimates, and where he cannot acquire anything save what he grinds out of his chief contractor on the one side, or out of his workmen on the other, is one of a class which, like his middleman prototype, stands as a shield between the faults of his principal, and those to whom he (the principal) is responsible, and thus pursues his course for gain alone without advantage or responsibility to the proprietary. As illustrating the system, and showing the actual cost of work, I shall quote the principal and sub-contract prices per cubic yard, on the Wicklow Railway, as supplied to me by one of the resident engineers:—

	Earth, per Cubic Yard	Rock, per Cubic Yard	Masonry, per Cubic Yard
	s. d.	s. d.	s. d.
Principal Contractor. Pfice in Schedule, ...	1 2	2 6	10 to 15
Sub-contract Price, . .	0 7	1 9	7 to 8

These prices applied to all the Bray Head excavations and retaining walls, will show differences between the value and cost of railway work, which cannot fail to astonish the uninitiated.

Let the curious in contracts refer to the terms on which the Portadown and Dungannon Railway contract was last year negotiated with an Irish contractor, and concluded with a late celebrated, but insolvent English firm, and additional light will be thrown upon this subject.

The Derry and Coleraine Railway sometime ago fell into the hands of a railway contractor, having been unable to struggle through difficulties entailed by collusion and extravagance in the first contracts on the line.

I do not wish to take such extraordinary cases as those named for the basis of any calculation of saving to be effected in the execution of railway works, but, to the sums already set forth, I wish to add the fair differences between the average cost of certain works on railways not occurring on roads, and the price at which they may be executed.

For this purpose I shall adduce a few facts. The Newry and Enniskillen Railway, 4 miles opened up to the present time, has cost about £136,000. It is a single line railway through rock cuttings, with light works, and with but one station; the whole value of which is under £2,500.

There is no doubt that in its average cost per mile, it is the most expensive single railway in these kingdoms. During last year this line was extended to the Albert Basin in

the town of Newry, having been previously advertised for contract.

The prices in these tenders were ordinary moderate rates at which railway work is executed.

I have put them down in juxta-position with the actual cost of the work as executed afterwards by day work by the company, under the superintendence of their own engineer, to whose excellent advice and management the company is indebted for a saving equal to 60 per cent. of the amount in the tenders, and equivalent to 10 years of his salary.

Contractor's Tender				Cost executed by the Company				
	£	s.	d.	s.	d.	s.	d.	
Earthwork, Embankment,	0	0	9	0	3 to	0	4	All from Side Cuttings
Ditto in Foundations, .	0	1	0	0	3 to	0	4	
Rubble Masonry, . .	0	8	0	4	6 to	6	6	
Ballast, ...	0	1	6	0	8 to	0	10	
3½d per 4 Culverts, .	3	13	6	18	0 to	20	0	
	and 4	10	0					
Dressed Coping, . .	0	2	9	1	6			
Laying Way, . . .	0	1	0	0	6			

I do not put this forward to show that railway works can be executed *generally* on these prices, because there were favourable circumstances affecting some of the items, viz., the ballast and earthwork; but I have put the facts on record as containing a lesson on a vital subject, which men interested in railways should learn.

The cost of "Laying" by "the Permanent Way Company" is about £105 per mile; the price asked by the contractor who tendered for this contract, was 1*s.* per yard, or £88 per mile, whereas it appears that this permanent way cost the Newry and Enniskillen Company, under the superintendence of their own engineer, £44 per mile. I add, therefore, (after fair allowance for contractor's profit and superintendence,) to my former estimates of saving, £29 6*s.* 8*d.* per mile, on this item.

Ballast, for years past in railway contracts, has cost sums varying from 9d. to 2s. 6d. per yard, depending upon the nature of the material and the amount of haulage, but the average is about 1s. 6d., and this would not be an exorbitant price, if the ballast were (what it seldom is) unexceptionable in quality and quantity. I cannot, however, claim a saving to be made on this point, where the resident engineer is accountable, and where he may be wanting in inclination, power, or independence to carry out the specification.

There is another important item in which there is a field for saving, viz., in the price of land taken by compulsory power for railway works.

There has, doubtless, been a great improvement in the law regulating this matter, by which the old, tedious, and expensive "Inquisitions" have been abolished, and a Treasury arbitrator has been appointed instead.

There is still room for improvement; and I would here beg to suggest a further alteration in the law. What I propose is, that after the line is set out, and the contract plans made, that one valuator be appointed by the company, and one by the proprietors, who, with the assistance of the Treasury arbitrator as umpire, would have power to settle all land claims and accommodation works, and that the lodgment of their joint award in the union workhouse, as at present (the money being paid into court), should be sufficient to enable the company to take possession of the lands—leaving the final appeal, as at present, to the assizes.

By this arrangement the costs of arbitration courts, and of solicitors and lawyers, in the first instance, would be wholly dispensed with; as the valuation of all the interests would be quietly and fairly considered and fixed, from personal inspection, upon the facts and circumstances of the cases, without the excitement of courts, oaths, or advocates; and the final appeal, with its limited costs, would correct all the errors of

judgment or of accident, that these more rapid proceedings might entail.

I have no doubt that an average of £300 per mile might, in this way, be saved in the cost of the land for the single line railway.

There is in every schedule of prices a charge varying from 3d. to 1d. per superficial yard for trimming and soiling of slopes. The former is an old English price (and under English engineers was paid on the Dublin and Wicklow contract), but one penny is the usual sum in this country under Irish engineers—the former rate is unfair and exceptional—it is, therefore, to the latter rate that I address myself.

It is a notorious fact that the work under this name in the schedule is generally "scamped," or altogether omitted, in the execution. But even if it were honestly performed, the value of the labour of flinging a *film* of vegetable mould of infinitesimal thickness over the slope, and dusting the same with grass-seed, is far too highly paid for even at the lowest price in the schedule. Say that the slopes, on an average, measure five acres, or 24,200 yards per mile, the cost of this mythical operation to a company is £100 16s. 8d. per mile, or £20 per acre.

ESTIMATE.

One man will, at 2s. per day, trim 1,000 superficial yards of slopes per diem, therefore 24,000 yards per mile will cost . . .	£2	8	5
Soil 4 inches deep (excavation previously paid for), cost of removal to a convenient place, return, and spreading, at 3d. per cubic yard, for 2,689 yards, ...	33	12	3
Best mixed grass seeds, at 1½ bushel per acre, 15s. per; 5 acres, at 22s. 6d., ...	5	12	6
Contractor's profit, 20 per cent., ...	8	0	0
Total, ...	£49	13	2

Making, as nearly as possible, £10 per acre, or one halfpenny per superficial yard. I take credit, therefore, for a saving of £50 per mile under this head of trimming, soiling, and sowing slopes.

I shall now recapitulate the savings which I have estimated.

Land, 10 acres, at £30 per acre,	£300	0	0
Excavations, 30,000 yards, at 1½d. per yard,	187	10	0
Masonry rubble, 800 cubic yards, at 1s. 3d. per cubic yard,	50	0	0
Culverts, 60 lineal yards, at 50s. per lineal yard,	150	0	0
Ashlar, in quoins, string rings, and coping, 1,200 cubic feet, at 6d. per cubic foot,	30	0	0
Timber, in piling and overstructures, 700 cubic feet, at 1s. 3d. per cubic foot,	43	15	0
Fencing, 4,000 yards, at 7d. per yard,	116	13	4
Laying permanent way, 1,936 yards, at 4d. per yard,	32	5	4
Trimming and soiling of slopes, 5 acres, at £10 per acre,	50	0	0
Total,	£960	3	8

From this estimate it appears that the saving to be made is nearly £1,000 per mile even on low-priced Irish railways, and that this saving can be made by a descent from "the monster contract system," is a proposition which I believe can be well and practically maintained. The anomalies appearing in prices in this paper are extraordinary. The principal one is that from the year 1838 to 1845 (a time during which there was no rise in the labour market), the price of the cubic yard of earthwork doubled itself; and in the period between 1845 and 1857, when the price of labour was steadily increasing, the cost of all descriptions of railway works was as steadily on the decline—the price of the article produced being inversely as the cost of its production! Increased knowledge on the part of the employer and employed, and greater skill in the possession of the artizan and labourer, should point to decreased prices during the first epoch; and increased labour rates should have produced increased cost of works in the latter period—if all the contracts had been fairly and honestly entered into and executed. But want of knowledge on the part of some boards of directors, and want of money, or honesty, in others —want of faith in the power of their own countrymen to execute the works in a few, together with the cupidity of

adventurous contractors, conspired to produce the prices which have enriched the latter and beggared the former—and these feelings and circumstances, by prevention of fair open competition, account sufficiently for the anomaly.

I do not alone censure the contractor who gets an unfair price for his work. He is, if anything, less to blame than the directors, who, to save time or trouble, neglect the interests of which they are the elected guardians, and let their contracts from 15 to 50 per cent. above the value of the work.

It is reasonable to assume that the cost of any work will be to a certain extent in proportion to the number of persons to whose competition it is open. Very large capitals are held by the few, and small capital by the many, consequently if we confine the competition to the former class, the prices demanded will be higher than if the work were within the range of competition of the latter.

Let therefore these works be so divided as to bring them everywhere within the reach of the smaller capitalists, and the most beneficial results will follow.

To carry out this system, contract works should be so classed as to give the greatest facility to suit the letting to, and execution by, the small and competent contractors, whose employment I advocate. And should it so happen that one person got two or three separate portions of the work, the company would have the advantage of their letting, subject to the greatest competition, and consequently at sub-contract prices.

This is no new idea. I only wish to see restored the former or earliest state of things as they existed on the first great railway executed in the world. The Liverpool and Manchester line was made, not by a monster contractor—the genus was not then in existence—but by the small contract system, under about 16 different contracts, in the hands of about 25 contractors and under the direction of seven engineers and

four superintendents of works; a complete list of which I subjoin.

Name of Work.	Resident Engineer.
George Stephenson,—*Engineer-in-Chief.*	
Liverpool Tunnel	Mr. Locke.
do.	Mr. Gooch.
Manchester Works	Mr. Dixon.
Intermediate Works	Mr. Holkyard.
Sankey Viaduct	do.
do.	Mr. Fife (*Assistant*).
	Superintendents of Works.
Tunnel at Liverpool to Roby	Mr. Harding.
Whiston Plane	Mr. Scott.
Salford Bridge	Mr. Fife.
Olive Mount Works	Mr. Gillespie.
	Contractors.
Cutting between Salford and Chat-moss	Mr. Robert Stannard.
Chat-mos	Mr. Blacklock, Mr. Wyley, and others.
Brosely Embankment	Mr. John Blacklock.
Thence to Newton	Mr. John Baird, and Mr. Robert Hutchinson.
Sankey Embankment	Mr. Greenshields.
Sulton Excavation	Mr. Thomas Eaton.
Ramhill, Cutting in rock, &c.	Mr. James Copeland, Pickering, and Co.
Whiston Cutting	Mr. M'Cloud, and Mr. Alcock.
Great stone Excavation, Olive Mount	Messrs. John and George Stevenson.
Marl Cutting, thence to Wavertree Lane	Messrs. Thornton, and Co.
Tunnel Mouth, or Edge Hill Excavation	Mr. Thomas Harding.
Tunnel Excavation	Mr. J. Copeland, Mr. J. Stevenson, and Mr. J. Harding.
Newton Viaduct	Mr. George Finlay.
Rainhill Skew	do.
Irwell Bridge	Mr. Brockbank and another.
Water Street Viaduct	do. and Mr. Findlay.

I think it well to insert this list, and thus to record the fact that such was the system in the execution of the first great railway in the world, and in doing so I think I may safely add the reflection, that it would have been well for shareholders and engineers that all the great works since executed had been carried out with the same economy and integrity as those of

that great first railway, planned and executed in that glorious era, when jobbing between contractors and directors was unknown.

That the Liverpool and Manchester Railway was economically made under this system, will appear from the following figures:—

	£	s	d.	£ s. d. Per Yard
The Great Tunnel, 1,980 yards long, double line, 22 wide, and 16 feet high, (⅓ lined with brick,)	34,770	0	0	17 10 0
Small Tunnel, 291 yards long, single line, 15 wide, 12 high, ...	2,480	0	0	8 12 0
Sankey Viaduct, 9 arches, 50 feet span each, 70 feet high, piling 30 feet deep, all ashlar work, ...	45,000	0	0	—
Excavations, 31 miles, double line, with heavy works, £200,000; Chat Moss, 4¾ miles, £27,000, ...	227,000	0	0	Per Mile 7,300 0 0
Whole Cost, inclusive of Land, Rails, Stations, Salaries, Cost of Act, &c., . . Average Cost, £26,451 per mile.	820,000	0	0	—

The average cost of all the English railways, single and double, being to this date nearly £40,000 per mile.

There is special reference made in this paper to the great differences between the prices on the first and last contracts on the Ulster Railway. Some light will be thrown upon this subject by reference to the published report of the proceedings of a meeting (recently held at Belfast) of the shareholders of "the Belfast and West of Ireland Railway Company," for the purpose of amicably and quietly winding up the concern without the intervention of the Court of Chancery.

The principal business of the day was to relieve a contractor from the pecuniary pressure of £7,000 of deposits on shares to the amount of £70,000, which he had taken when the Bill was in Parliament in 1853, under a secret arrangement with the managing committee that he should not be held responsible for more than 100 of the 2,500 shares for which he had signed the subscription contract. After a noisy discussion, a protest

on the part of a shareholder, and an adverse speech and amendment, the meeting most "honourably," (to use the words in the report,) relieved the contractor from the payment of the £7,000, and took it—against law, and reason, and suffering humanity, upon themselves to pay, in addition to their individual liabilities on their own *bona fide* shares.

In this report will be found the reason for the difference in prices under small and great contracts. Had the Act been obtained, the shares would have been the *bona fide* property of the contractor, and the man who would have dared to insinuate that there was any such secret arrangement about them, as is now proved, would have been looked upon as the reviler of this great and good man, who afterwards would have become the contractor for the work by *virtue* of the previous arrangement.

The Ulster Railway Company of 1837 did not need to enter into collusion with a contractor by which he should take £70,000 worth of shares, and to sign the subscription contract for the amount, with a mental reservation—or do an act which he knew to be binding in law and honesty, but from which (in case he did not get the contract for the bribe,) he was to be released by the outraged code of honour. They did not need to enter into any arrangement with a monster contractor by which he should be secured against loss in the depreciation of his shares—as regards the directors for the purposes of the Bill in its passage through Parliament, and as regards the contractor for the purpose of securing the contract at prices beyond the fair value of the work. That such things should exist in the present day, and in the Province of Ulster, is a scandal and a shame; and that engineers should submit to hold office where they exist, is a matter of astonishment.

It is well for such contractors, however, that there has always been, according to an ancient proverb, a spurious sense of honour regulating actions which are in themselves dis-

honourable. Had the proverb not held good in this case, the contractor would have paid £7,000 for his jobbing, (which he may have yet to pay,) and had the Bill passed into law, the shareholders would have paid, in their schedule of prices, the full value of the name and figures in the subscription contract.

I select this illustration out of many such cases, because it is the most fresh in the recollection of the meeting and the public, and because the facts stated are unquestionable; and I close this section of the paper with a quotation from the unpublished portion of the paper (on the subject of single and double railways,) read by me at this Institute two years since.

"In former times, books, plate, and works of art, and luxury of every description were so expensive, that few could purchase them; now, from greater skill, more knowledge, and an increased number of artizans, they are produced at prices which enable many to possess them. So long as railways were unknown and difficult of construction, with few hands skilled in their execution, it was inevitable that large prices should be paid; but now, when the art of making railways is well and generally understood, and when they have become things, not of luxury, but of absolute necessity, it is proper that they should come to their fair price in the market."

I have only to add, in concluding these observations upon the cost of works, that the savings which I have shown to be available, are upon what are considered fair Irish prices of railways as at present existing—the saving to be made upon the prices of works let to contractors, under secret or shareholding arrangements, I do not attempt to arrive at—they are in the compound ratio of the financial positions into the moral condition of the contractors and directors of the companies. They may, however, be guessed at by the intelligent engineer, from the materials for thought or calculation which I have supplied in those pages.

The price of a work is a question not affecting the character of the engineer, when he, the engineer, has no control over the letting of the contract, which state of things is almost constant; and, if works were executed according to his designs, on prices agreed upon between the contractor and the directors, he could not object to their expenditure of their own money on a scale which would place within his reach the means of executing works of excellence and grandeur; but when those prices given for works under his superintendence tend to limit his power, and wrest from him his control of the contractor—to invert their respective positions, and to destroy his independence and usefulness of action, it is then time that he should stand upon his defence, and if the attack of the system which causes such a state of things be requisite, it is his duty to himself and to his profession to strike strongly and repeatedly at the root of the evil. It has been suggested to me that we should be careful how, in any paper read at this Institute, we should attack a class of men who, by the greatness of their wealth and undertakings, furnish so much employment to our profession. Who, before the present corrupt era in railway contracts, ever heard of the builder being the employer of the architect? The reverse has ever been the case! Is not the stereotyped phrase in all deeds of contract—"according to the specification, and to the satisfaction of the engineer." These words mark clearly the respective ranks and positions of the two classes. I understand their meaning to be, that the designer and judge of the work cannot be said to be the person patronised and employed; and thus I see no reason why I should spare the condemnation of evils because they are the evils of a class which has grown to giant proportions through the faults of our profession.

Let me not, however, be understood to condemn any man individually. If I point to localities by which men can be identified, I do so for facts upon which to base my argu-

ment or my comment, and I do not quarrel with the men but with the circumstances. I am, however, free to acknowledge, that so long as I am not (by any error of observation or information) doing injustice, it shall give me no trouble if men of character and circumstance smart under the censure.

The Wicklow Railway contract, then, was perhaps one of the most striking instances of false position on the part of the engineer and contractor of any which occurred in any country. The Engineer-in-chief resided in London and his permanent staff consisted of a resident engineer and two assistants. The designs were made in London, and contract drawings were from time to time supplied to the contractor, showing the forms and dimensions of the works to be executed under a schedule of prices previously agreed upon. These drawings were carefully brought under the notice of the contractor, and as regularly were they (except in a few rare instances) thrown aside. The contractor's "man" designed and executed better works for the company, and for his master.

Assistant engineers represent this state of things to their resident. Their resident orders the work to be executed according to the designs of his chief. The contractor's "man" promises attention, but says he must obey the orders of *his* employer, and that "his honour" must procure that order in writing before he can obey him. The resident wrathfully rushes to the board of directors and makes his complaint. His defeat and astonishment are complete when he sees that the contractor, *his* contractor, is at the board, and is, to all intents and purposes, the principal shareholder and director—in fact *his* employer and master; he retires subdued and snubbed. The works are executed in the perfection of taste, art, and science upon the designs of the contractor's "man," whose stoicism under the entreaties and threats of engineers has perhaps raised him from the rank of the navvy to his present position of trust and favour with his all-powerful employer.

Let it be added here that the work on the Wicklow contract was ultimately measured up and paid for by the schedule of prices on the exact quantity executed—a circumstance which in some measure atoned for the previous errors of position and conduct.

What state of things can be more destructive of the character and position of the engineer? Should any engineer submit to occupy such a position? It is a proud boast that there is hardly a blot upon the professional escutcheon. There is poverty, timidity, want of self-respect, want of firmness, and crushed independence; but I cannot in our profession name three men in these three kingdoms, upon whom the curse of a dishonourable name has fallen.

The substitution of the small for the great contract system would improve the position and increase the employment of the engineer. The position would be improved, because the contractor would be unable by his wealth or position to overawe, corrupt, or bully the engineer. The small contractor, on account of his reduced prices, should do his work without deputy, and would, therefore, be constantly found in its immediate superintendence. By this arrangement the fair profits on the construction of railways would be distributed over a great number of individuals, and industry, instead of jobbery and capital, would have the reward. By the personal superintendence of the contractor, the orders of the engineer would have immediate attention and respect, and it would be difficult to delay the execution of an order on the pretence of waiting for the presence of the principal—an old and discreditable artifice, by which work is scamped, and the terms of specifications evaded.

As the system affects the position of the engineer, the most serious evil is that each monster contractor has a staff of men in regular training and work—generally taken from the rank of navvies and gangers, or who are the sons of these people, who supersede the engineer in his legitimate duties on the

works where they are trained—who often afterwards take the style and title of civil engineer for themselves. In the adoption of the small contract system this evil would be abated, inasmuch as they would be superseded by assistant engineers, employed by the companies, who would be the advanced pupils of the residents or engineers-in-chief, by which means a spurious class of men would be prevented entrance to the profession, and its legitimate aspirants would have increased opportunities of receiving the education and the experience from which honour and emolument alike flow.

The great circumstance affecting injuriously the position of the engineer, and that most requiring to be corrected by legislation, is that which allows a shareholder in a company to become a contractor for its works—or the paid servant of a contractor to be a railway director, in right of shares purchased with his master's money. If these evils could be corrected, a great change would be made for the advantage of the engineering profession, and to any enactment on the subject should be added a clause to hinder subscription contracts from being cooked by the addition of the subscriptions and names of railway contractors: and in case of such being made in a *bona fide* manner, to prevent the person holding such shares so subscribed from afterwards having, directly or indirectly, any connexion with the contracts under the company.

There is legislation to prevent Poor Law Guardians, ex-officio or elected, from participating in any way in any contract in the Union in which they hold office, and though there is not, in all cases, direct legislation on the subject, yet the position is one of so much suspicion, that Grand Juries, Governors of Public Charities, and Directors of Public Boards generally, keep themselves free from the taint of such disgraceful transactions. It is now several years since a certain railway king taught the world a royal lesson on this subject, and the disclosures then made pointed clearly to the necessity

for legislation on the subject; but the sense of danger returns to its dulness when the shock of a recent calamity is over, and the frauds then practised by the king of jobbers have been reproduced with impunity, with more or less variation of form and circumstance, but with slight difference of moral turpitude, to the present time, and the practice is now as uncontrolled as if Honour and Honesty were not loudly calling upon Law for a strong arm to aid in its suppression.

It will be said that contractors are benefactors to society in the manner by which they assist in railway enterprize. No doubt they take prodigious quantities of shares, and the world does not know in what manner they are taken or paid for, and the same desideratum is afforded to the communities who are convenienced by the works, as if they were executed at a nominal cost. This is true to a certain extent; but it is also certain that if railway works could be reduced one-half in cost, the tariff for the carriage of all classes of passengers and goods might be reduced one-fourth, leaving the same dividends to the shareholders.

It is undeniable that contractors raise vast sums of money for the formation of railways, and it is believed that they do so upon their own superior personal security, whereas a moment's consideration will show that it is upon the security of the works—on the security of the directory and proprietory of the undertaking that they are enabled to raise the capital which they expend or apply.

This being the case, why should it exist? Why should railway directors go into the money market for accommodation through the agency of a contractor? The spendthrift who borrows money from the Jew is not more immoral or unwise. He goes to *one* Jew and pays usury for the loan. They go to the same Jew, but through the medium of a Christian, whose usury is more ruinous than that of the Israelite. The contractor, in negotiating the loan, exhibits his contract deeds

as credentials, and mortgages the scrip of the company as security. Why, then, should the company not be its own borrower? If money can be got upon its security *second-hand*, how much more easy to obtain it *directly*, and save the cost of the agency! especially when that agency goes to complicate other transactions, and poisons the spring from which the prosperity of the company should flow. But the question remains—How is the subscription contract to be made up? How shall three-fourths of the whole capital be shown to be subscribed for in a *bona fide* manner? There is hardly such a thing in these times as the honest fulfilment of these conditions, and as I look for no improvement except by altered legislation—*i. e.* by altered standing orders—I would suggest that the amount of subscribed capital should be lowered, and borrowing powers to companies extended—excluding the name of every person who might appear to have exorbitant pecuniary interest in his shares, whether Jew or Gentile. And should the subscribed capital for the whole work in the bill not be made up by the time of its second reading, then the committee should limit the extent of the work to suit the amount subscribed. In this manner the instalment of a work might be honestly entered on, and executed with all possible forethought and economy; and the complexion thus given to it might, and most probably would, have the effect of improving its character in the market, and of making its extension easy in after sessions of Parliament, without extending the time necessary for its complete opening, as at first contemplated.

In Egypt, the cradle of engineering, the greatest constructive works in the world were executed in the early times (it is presumed) by a multitude of hands, directed by one mind and management—that of the engineer and architect—and some of those names are more lasting than the monuments which they erected for the glory of the nations and themselves. That Dinocrates, who rebuilt the Temple of Diana at Ephesus

and built the new city of Alexandria for the great son of Philip, was not obliged to hand over his laurels to any workman engaged to carry out this design. Neither did any of the 400 men in the starry line of architects and engineers, from his time to the present century, whose works have made empires great and the reigns of kings glorious. From Eupalinus, who, in the sixth century before Christ, built the first acqueduct in Samos, to George Stephenson, who made the first railway in Britain, the engineer and the architect had the position and credit due to his work. The architect is still in possession of his laurels, for the builder has not yet grown into a monster of such vast proportions as the railway contractor, and there is no case yet on record of his having thrown the designs of his architect to the winds, and executed the building upon the amended plans of his foreman mason or carpenter. He is still the master and the judge—the structure is according to his designs, and he reaps the credit or the shame of its erection from his employers and from the world. Not so the engineer! Ask who made the first railway in Ireland. The name of the contractor is readily given in answer. Ask in Liverpool or in London who are at this moment building the Mersey Docks, in which a million and a half is being expended. The reply will give you accurately the names of the monster contractors for the work. Ask who has the merit of the Great Southern and Western—the Midland—the Drogheda—the Ulster Railway—the Belfast Harbour Works—the Dublin Graving Dock. The universal answer will be the name of the man who was the contractor, and few, indeed, in the counties in which these works are situate, will be able to tell who the engineers were by whose science, skill, and industry, these works have been designed and executed.

Engineers from time to time have had great assistance from monster contractors in the rapid execution of work, which vast capital and plant can command; but works in civil engineer-

ing are seldom if ever required to be executed in great haste, and the enormous increase of power and cost, which are inseparable from rapid motion in either machinery or works, make the advantage doubtful. In military engineering, it is true, the advantages of rapid execution are great, and the application of the system to the construction of the Balaklava Railway, and in the execution of every description of siege and field work, is a practical illustration of its advantages in a military point of view, where the cost of the work is never a criterion of its value. Sudden and dangerous breach, or accident, or injury alone, can justify expenditure of this description, and at such times professional position and etiquette may be safely set aside for the safety of the life or the property jeopardized.

In the early days of railways, the contractor was an individual who, like any other builder or trader, undertook and carried out works under the direction of a superior animate unit called an engineer; now the contractor is the principal shareholder, and the engineer is a negative quantity in the calculation.

This prince amongst men is now everywhere tufted and flattered. He is king of Railway directors—sits in the secret chamber—pulls the wires by which the automata work, and lets the contract of the company to himself. He is the guest of royalty. His carriages, horses, yachts, mansions, plate, and retinue are the envy of princes!

He is a conjuror more celebrated than the wizard of the north; by the stroke of his pen he makes a subscription contract good or bad—and *presto!* a bill is turned out of doors and lost. Has he a good bargain with the committee of the company, by which bright gold is beaming in the future, you will hear him giving evidence for the bill, and vouching for the estimates. Is that bill in difficulties (if he be not a member of the house) look for him in the lobby when the Speaker is at prayers; should he have *that distinction* due to his great

wealth, patriotism, and philanthropy, you must go within the doors of hallowed St. Stephens, and seek him on the back benches where he will be found conversing in whispers with members of committee. He is a character of the most infinite self-possession and coolness—Bumble and Brunel are names with alike respect and terror for him; he annihilates an engineer without an effort—spurns or treats with contempt his authority—is deaf to orders and remonstrance—does not deign to reply to his letters—keeps with him no appointments—does all by deputy. The engineer refuses to certify—the contractor goes to the board—the directors *pay* the one, and *snub* the other; and things go on revolving in the same delightful order till the day of reckoning which seldom comes; for he is in these cases to all intents and purposes, the board of directors —engineer—contractor, and company, in his own person. What then is the advantage to the engineer that this incubus should lie upon his profession.

Does he barter his position for money? No—the honour of the profession is almost unimpeached.

Is it religion that makes him submit to be trampled upon by the class which is naturally subordinate to him? Alas! I fear that the profession is not distinguished above others for christian virtues; why then does he spend his life in a constant struggle with "a power which he has raised and cannot control?" It is indolence that has entered into his soul! The want of determination to strike that blow which he has the power to strike, and under which the giant would fall beneath his feet. The nature of that blow is already indicated in these pages.

Joseph Gwilt, the engineering and architectural writer, gives a definition of the word *architect;* it applies also to the engineer, and is worthy of quotation.

He says, an architect is a person competent to design and superintend the erection of works; that "he should with a

perfect knowledge of his profession, have devotedness, faithfulness, and integrity to his employer, with kindness and urbanity to those whose lot it is to execute his projects, and with resolution *at all times promptly to check the dishonesty of builders or contractors, should he meet with such! Qualities,"* (he adds,) "which must insure a brilliant and happy career in his profession."

I have only to add to the definition of Gwilt, one other quality, which is, a determination not to hold office or employment from any individual or company where the builder or contractor is allowed to depart from the specification, or to do any act injuriously affecting his position or authority.

Poverty and the arts and sciences have, since the beginning, been constant companions, and although, (save in the very highest ranks,) the engineer is not paid in proportion to the value of his services, I do not here advocate his just claim to increased compensation; but I claim for the engineer the position which should be his by prescriptive right, and by right reason, and I look for the united efforts of the members of this Institute to remove the stain which at this moment lies upon the profession, viz., that the resident engineer on railway works often prefers broken specifications and daily bread, eaten in subserviency and indolence, to the manly, honest, and independent course, which would enforce the terms of the contract, though it might deprive him temporarily of employment, and make an enemy of the great man—THE MONSTER CONTRACTOR.

APPENDIX.

ULSTER RAILWAY CONTRACT, No. 1.

27,280 yards lineal fencing, at 6d. per yard,	682	0	0
Temporary ditto, with quicks, at 7½d. per yard,	50	0	0
1,240 yards lineal tiles, at 9d. per yard,	46	10	0
Excavating, 5½d. to 6d.,	11,325	4	0
Bridges,	12,115	3	9
Plan No. 3, Blackstaff wall and river,	50	0	0
Culverts,	1,016	2	0
Paved crossings,	192	0	0
Plan No. 3, additional charge,	94	9	8
Levelling and forming road,	1,775	0	0
To building of brick or stone culverts, including foundations, fronts, wing walls, &c., viz.:			
Culverts of brick, 1 foot in diameter, at per cubic yard,	1	2	6
Do. do. 1½ ,, ,,	1	1	0
Do. stone, 1½ ,, ,,	0	12	0
Do. brick, 2 ,, ,,	1	0	0
Do. stone, 2 ,, ,,	0	12	0
Do. brick, 3 ,, ,,	0	17	0
Do. stone, 3 ,, ,,	0	10	0
Do. brick, 4 ,, ,,	0	16	0
Do. stone, 4 ,, ,,	0	10	0
Do. brick, 5 ,, ,,	0	16	0
Do. stone, 5 ,, ,,	0	10	0
Do. brick, 6 ,, ,,	0	15	6
Do. stone, 6 ,, ,,	0	10	0

Schedule of Prices, 9 Miles, 926 Yards.

DUNDALK AND ENNISKILLEN RAILWAY—FIRST CONTRACT.

May 5th, 1846.

Fencing ditch and mound, sods and quick, per lineal yard,	0	1	6
Fencing post and rail planed, per lineal yard,	0	3	6
Rough larch, per lineal yard,	0	2	6
Price of excavation in earth, per cubic yard,	0	0	11
Rock, per cubic yard,	0	2	2
Foundation, per cubic yard,	0	0	6
Drains, per cubic yard,	0	0	6
Soiling slopes, per superficial yard,	0	0	1

Approaches—When embanked from railway or side, per cub. yd.,	0	1	0
,, Formation of roadway, per lineal yard,	0	2	6
Box, ballast and pitching, per cubic yard,	0	1	6
Pitching for altered roads, per cubic yard,	0	1	8
Metalling for ditto, per cubic yard,	0	2	0
Masonry in foundations, per cubic yard,	0	6	0
Rubble, per cubic yard,	0	8	0
Hammer-squared work, per cubic yard,	0	15	0
Ditto in parapets, per cubic yard,	0	15	0
Arched sheeting, hammered stone, spiral or straight, per cub. yd.	0	17	0
Ditto, in brick rings, per cubic yard,	0	18	0
Blocking course of rock ashlar, 18 inches deep in facing, abutment, rings, spandrils, &c., per cubic yard,	1	0	0
Plain string course, coping of parapets, wings, caps, &c., &c., per cubic foot,	0	2	0
Dressed ashlar, in cornices, chamfered or plain arris, tooled round arrises, and sparrow-picked between, per cubic foot,	0	2	0
Moulded cornice, per cubic foot,	0	3	6
Brick work (tuck pointed), per cubic yard,	0	18	0
Brick work set in cement, per cubic yard,	1	5	0
Pointing brick work, per superficial yard,	0	0	6
Pointing stone work, per superficial yard,	0	0	3
Concrete, per cubic yard,	0	4	0
Puddle over arches, per cubic yard,	0	1	0
Culverts, including foundations, 9 feet (stone), per lineal yard,	6	0	0
Do. do. 6 feet, per lineal yard,	4	0	0
Do. do. 5 ,,	2	10	0
Do. do. 4 ,,	2	0	0
Do. do. 3 ,,	1	10	0
Drains, do. 2½ ,,	1	0	0
Do. do. 2 feet square,	0	15	0
Do. do. 18 inches, per lineal yard,	0	10	0
Do. do. 15 ,,	0	5	0
Do. do. 12 ,,	0	2	6
Rubble drains, in slopes across roadway, or along dwarf walls, per lineal yard,	0	1	6
Cast iron, in girders, fixed, per lb.,	0	0	1¼
Wrought iron in girders, including bolts,	0	0	3
Timber Work—Pitch pine piles, driven in water, including heads and shoes,	0	4	6
Red pine in foundations, including heads and shoes,	0	4	0
Framed, trussed, or wrought timber in bridges, Memel, including paint, spikes, and planking,	0	4	6

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Red pine framed, or planking planed or spiked,	0	4	6
Do. do. not planed,	0	4	0
Price of laying permanent way, single line (two lines of rail), all materials to be delivered by the company, per lineal yard,	0	1	6
Rubble breast walling, built dry, per lineal yard,	0	2	6
One pair of iron gates, red pine posts, lock and hinges complete, and one paved crossing, including approaches, culverts, &c.,	30	0	0
Bridges—1,	1,062	0	0
,, 2,	185	0	0
,, 3,	1,370	0	0
,, 4,	960	0	0
,, 5,	1,220	0	0
,, 6,	1,020	0	0
,, 7,	680	0	0
,, 8,	560	0	0
,, 9,	380	0	0
,, 10,	318	0	0
,, 11,	295	0	0
,, 12,	680	0	0
,, 13,	215	0	0
	8,945	0	0

KILLARNEY JUNCTION RAILWAY, 1852.

Trimming and soiling slopes, per superficial yard,	0	0	1
Excavation in earth, per cubic yard,	0	0	8
Excavation in rock, per cubic yard,	0	2	0
Diversion of rivers and streams,	0	0	6
Earth work in road approaches, per cubic yard,	0	0	8
Road metal and pitching, per cubic yard,	0	2	0
Ditch and mound fence, per lineal yard,	0	1	0
Fences on embankment approaches, per lineal yard,	0	1	6
Ballast and boxing, per cubic yard,	0	1	3
Laying permanent way, per lineal yard,	0	1	6
Public road level crossing,	50	0	0
Ten foot culverts, per lineal yard,	9	0	0
Eight foot culverts, ,,	6	0	0
Six foot culverts, ,,	5	0	0
Five foot culverts, ,,	4	0	0
Four foot culverts, ,,	3	0	0
Three foot culverts, ,,	1	10	0
Two foot culverts, ,,	0	10	0
Fifteen inch drains, ,,	0	6	0

LIMERICK AND ENNIS RAILWAY.

Schedule of Prices for Contract Works, Extra Works, and Additions or Deductions from Contract Works.

Excavations, exclusive of rock, whether wheeled to spoil or removed to embankments, per cubic yard,	0	0	10
Rock cuttings, per cubic yard,	0	2	4
Excavations in road approaches, when made from side cutting, per cubic yard,	0	1	0
Excavations in road approaches, when made from rock in side cutting, per cubic yard,	0	2	6
Fence, ditch, and mound, with quicks and wire paling, per lineal yard,	0	1	2
Excavations for foundations, per cubic yard,	0	0	9
Masonry in abutments, broken ashlar, including backing, per cubic yard,	0	10	0
Masonry in foundation, backing, retaining walls, and buttresses, rubble, per cubic yard,	0	7	0
Hammered square arch sheeting, per cubic yard,	1	0	0
Spandrils, broken ashlar, including backing, per cubic yard,	0	15	0
Rock-faced and drafted string course, 18 in. by 6, per lineal foot,	0	2	0
Rock-faced and drafted impost blocking course, and wing wall coping, per cubic foot,	0	1	6
Pitched faced ashlar quoins, newals, and pilasters, per cubic foot,	0	1	6
Punched and chamfered ring pens, per cubic foot,	0	2	6
Rock-faced and drafted ring pens, per cubic foot,	0	2	0
Punched parapets (two faces), per cubic yard,	0	18	0
Punched and chamfered newel caps and plinth course, with chisel-drafted arrises, per cubic yard,	0	2	6
Coursed ashlar, in abutments and piers, per cubic yard,	1	5	0
Framed Baltic timber in bridges, per cubic yard,	0	4	0
Malleable iron girders, fired and painted in three oils, per cwt.,	1	4	0
Malleable iron, in bolts and straps, per lb.,	0	0	3
Clay puddle in arches, or behind masonry, per cubic yard.	0	1	0
Road diversions, exclusive of fencing, where excavations or embankments do not exceed 3 feet, 25 feet wide of altered surface, per lineal yard,	0	6	0
Ditto, 12 feet wide, of altered surface, per lineal yard,	0	4	0
Fencing to road approaches, per lineal yard,	0	3	0
Paved flagged drains, 2 feet square, per lineal yard,	0	10	0
Culverts arched, and with inverts, 3 feet, per lineal yard,	1	10	0
Do. do. 4 feet, do.	2	0	0
Do. do. 5 feet, do.	3	0	0
Do. do. 6 feet, do.	4	10	0

Painting timber, per square yard,	0	1	0
Farm-road bridges and cattle passes, each,	80	0	0
Public road level crossings, with simultaneous acting gates,	100	0	0
Field crossings (gates and approaches),	20	0	0
Ballasting and boxing, including trimming, &c., per cubic yard,	0	1	6
Stone pitching, per cubic yard,	0	1	4
Laying permanent way, including carriage and materials, per lineal yard,	0	2	0
Retaining walls at foot of cuttings, and embankments 1½ cubic yards to the yard forward, per cubic yard,	0	5	0

BELFAST AND BALLYMENA RAILWAY.

Schedule referred to in Specification.

Permanent fencing, per yard, including quicks,	0	1	0
Dwarf walls, in excavations, per yard lineal,	0	7	0
Pitching and ballasting of the permanent way, per mile, of double line,	650	0	0
Boxing of the permanent way, per mile, of single line,	330	0	0
Laying permanent sleepers, rails, and chairs, per mile, of single way,	212	0	0
Maintenance of permanent way, for 12 months, single line,	145	10	0
Level crossings and gates, complete, for field or occupation roads, according to No. 3 Plan,	50	0	0
Level crossings for public roads, gates, complete, according to drawings, No. 4 and No. 4*a* Plans,	75	0	0
Price of excavation, in foundation of bridges, &c., where scooping and pumping necessary, per cubic yard,	0	1	0
Rubble drain, in cutting, with tile at bottom, as specified, per yard,	0	9	0
Building 18 inch brick or stone culverts, including front and wing walls, with pumping and puddling, per yard lineal,	0	10	0
2 feet 6 inches Culverts of stone, per lineal yard,	1	5	0
3 ,, 6 ,, do.,	3	0	0
5 ,, 0 ,, do.,	4	0	0
7 ,, 0 ,, do.,	6	0	0
8 ,, 0 ,, do.,	7	0	0
10 ,, 0 ,, do.,	8	10	0
Occupation Bridge, as drawing No. 22,	360	0	0
,, ,, 23,	450	0	0
,, ,, 24,	220	0	0
,, ,, 25,	200	0	0
,, ,, 26,	160	0	0

Rubble masonry, in mortar, including labour and materials, per yard, cubic,	0	7	6
Hammer dressing on face, per yard, superficial,	0	4	0
Pick dressing on face, per yard, superficial,	0	6	0
Brick-work (Dungannon fire bricks,) in mortar, plain work, including labour and materials, per yard, cubic,	1	12	0
Brick-work in arches, in mortar, per yard, cubic,	1	12	0
Do. in cement, per yard, cubic,	2	2	0
Brick-work in cement, plain work, including labour and materials, per cubic yard,	2	0	0
Stone quoins of Tandree or Dungannon stone, dressed and set, per cubic foot,	0	2	0
Coping of bridges, as in specification, set, per cubic foot,	0	2	0
Spring courses, as specification, of do., per foot, cubic,	0	2	0
Metalling of turnpike roads, per yard, superficial,	0	1	6
Do. public roads, do.,	0	1	3
Do. farm or occupation, do.,	0	1	0
Excavation by barrow-runs of 25 yards, per cubic yard,	0	0	6
Do. for each additional run, per yard, cubic,	0	0	1
Excavation in gravel, till or clay, where lead is ¼ of a mile, per cubic yard,	0	0	8
,, ,, ½ ,,	0	0	9
,, ,, ¾ ,,	0	0	10
Excavation in gravel, till or clay (where lead is 1 mile), per cubic yard,	0	0	11
,, ,, 1¼ ,,	0	1	0
,, ,, 1½ ,,	0	1	1
,, ,, 1¾ ,,	0	1	2
,, ,, 2 ,,	0	1	3
,, ,, 2¼ ,,	0	1	4
,, ,, 2½ ,,	0	1	6
,, ,, 2¾ ,,	0	1	7
,, ,, 3 ,,	0	1	8
Timber in girders, piles, &c., per cubic foot,	0	4	0
Do. 4 inches planking, complete, including spikes, per superficial yard,	0	11	0
Timber wrought in hand-rail, fencing, gates, &c., per cubic foot,	0	5	0
Cast iron in girders and heavy castings, per ton,	15	0	0
Do. in railing and light casting, ,,	16	0	0
Painting in oil, 4 coats,	0	0	4

Act, July 21, 1845.

Opened, 11th April, 1848.

ULSTER RAILWAY EXTENSION.

Schedule of prices, 1856.

The price, per yard, of temporary fencing, . . .	0	0	6
The price of permanent fencing, consisting of ditching and quicks, at per lineal yard of single line, . . .	0	0	10
The average price of the whole excavations, with the slope of the excavations and embankments completed as described in the specification, at per cubic yard, ...	0	0	9
The price of brick-work, set in mortar, at per cubic yard, .	1	0	0
Do. do. in cement, do. .	1	6	0
The price of whinstone rubble work, set in mortar in random courses, at per cubic yard, ...	0	7	0
The price of ashlar, dressed and set, the faces of the stones chisel-dressed, at per cubic foot, ...	0	2	0
Do. do. do. rustic chamfered joints, at per cubic foot, ...	0	2	3
The price of string courses and copings dressed and set, at per cubic foot, ...	0	2	6
The price of paved crossings, referred to in the specification or marked in the section, at per square yard, . . .	0	7	0
The finding and erection of gates connected with the paved crossing, referred to in the specification or marked on the section, including posts, gates and fencing, at per gate, .	20	0	0
The price of laying brick or stone drains under bridges, at per lineal yard, ...	0	10	0
Metalling the surfaces of diverted roads, or roads forming the approaches to bridges or paved crossings, at per superficial yard, ...	0	0	9
The price of maintaining and keeping in good order the single line of permanent way, from the period of one year after the completion of the whole of the works, at per mile, . .	90	0	0
The price of excavations in foundations where pumping and scooping is necessary, at per cubic yard, . . .	0	0	10
The price per cubic yard of rock ashlar for bridges, as described in specification, ...	1	2	0

19th November, 1856.

[14th April, 1857.]

M. B. MULLINS, Esq., Vice-President, in the Chair.

"*On the* ECONOMY *of* SCAVENGING *and* REPAIRING *the* STREETS *of* DUBLIN, *compared with that of* SCAVENGING *and* REPAIRING *the* STREETS *of* LAMBETH, *in London*;" by R. H. FRITH, Esq., Member.

INVESTIGATION of the causes which tend to shorten the duration of human life in cities, is a work worthy of the philanthropist; and an Engineering association, in neglecting to point out defects, the removal of which would prolong life or alleviate the condition of the working classes, fails to discharge a duty to its country.

The health, comfort and longevity of the inhabitants of cities and towns, depend on an adequate supply of pure water, good drainage, and cleanly scavenged streets, lanes, and alleys; in proportion to the neglect of these sanitary essentials, contagion is propagated, and life abridged. "It appears from the Register-General's return, that the average duration of life in Bermondsey is only twenty-two years for the whole population," (caused by defective sanitary arrangements.)—*Evidence of Surgeon Wagstaff before the Metropolitan Sanitary Commissioners, page* 17.

Ancient rulers appear to have considered it their duty to provide an adequate supply of water for the cities under their dominion,—the Babylonians, under the direction of Queen Semiramis; the Egyptians, under Sesostris; the Hebrews, in the reign of Solomon; and the Romans, under Appius Clandius.

The great resources of the Romans, in men and money, enabled them to execute aqueducts for the conveyance of

water to several cities in the countries to which, by conquest, their dominion extended, as well as to those of Italy; and not only did they devote much skill and enterprize to the supplying of their cities with water, but provided them also with well-maintained streets and the most perfect and efficient system of drainage. In speaking of the latter, the talented author of the Antiquities of Rome says:—"I took some pains when the water was not very high in the Tiber, to examine the great sewer, now rendered useless from the deposit at its mouth. and the great elevation of the bed of the river above what it was when this sewer was constructed. It is 14 feet in width, and 32 feet in height, constructed of large and massive blocks of Albano stone, called pepperino, and has a semicircular arch formed of three rings of voussoirs."

Those silted-up sewers now form elongated cesspools, and send forth miasma containing contagion, disease, and death, to remedy which, Pio Nono considered it necessary to retain the professional services of Mr. Henry Austin, C.E., for the purpose of reporting on the best system for re-establishing the drainage of the Eternal City.

What has occurred in the Tiber, is only prevented from occurring in a less degree in the Liffey, by the well-directed exertions of the Ballast Board.

In considering the comparative suitability of pavement or Macadamizing for streets, and the scavenging, repair, and maintenance of them, in places differently situated, and at a distance from each other, it will be necessary to compare of those places, *severally*,—1st. Climate. 2nd. Traffic. 3rd. Subsoil. 4th. The cost of procuring labour, and the several materials necessary for construction and repair; and in proportion as these bear on the execution and stability of the work, in either place, it becomes cheap or dear accordingly.

The effects of the climates of England and Ireland on Macadamized roads, consist in the disintegration of the surface

by frost, softening by rain, and ravelling from parching winds and heat. The two former injuriously affect city streets; the evil arising from the latter may be said to be neutralized by shade. I have not been able to find any authority on the exact cost of remedying the injury caused by frost to Macadamized carriage-ways, but from observation I am induced to charge an additional week's wear for the extra material and labour required for surface repair after a thaw of 12 degrees of frost. Rain is much more prevalent in Dublin than in London, especially in winter. The summer's excess of rain in Dublin, during its continuance, prevents the necessity, and consequent cost of watering. I am of opinion that the excess of frost in London, and its effect on the tenacious subsoil of the streets, balances the injurious excess of rain during winter in Dublin, and therefore consider the climates equal as affecting the maintenance of streets.

2nd. *Traffic.*—In the Lambeth district of London the traffic is at least 50 per cent. greater than in Dublin. Therefore streets should be maintained proportionably less in Dublin.

3rd. *Subsoil.*—In Lambeth the subsoil is wet, tenacious, and generally below the level of the tide; in Dublin it is dry gravel, and generally above the rise of the tide; consequently streets are more easily maintained in Dublin.

4th. *Material and Labour.*—On the convenience and facility of procuring these, depend the cost of maintaining a road in repair. The material used for the surface repair of the London streets is Guernsey granite—a stone inferior to the Dublin Trap-rock for road repairs. It is taken from a distance of more than 300 miles from London, and having been twice transhipped, is delivered on the streets in Lambeth, at 15s. 6d. per yard—which may be considered cheap, taking into account the distance and number of times it has to be shifted. The Trap-rock is, I believe, delivered

on the streets of this City, from the Dublin hills, distant under eight miles, for 6s. 2d. per ton, first having been discharged, unbroken, at the Contractors' depots at Fir-house, for 1s. 8d. per ton, and at Kimmage, for 2s. per ton. These unnecessary loadings and unloadings, added to the second profit for the Kimmage and Fir-house contractors, raises the price of the stone above its legitimate value. Were scientific appliances used in quarrying, it would ensure an adequate supply of stone, suited to the requirements of the traffic, and effect a saving of labour and expense.

The mode of repairing the streets of Liverpool has been brought under our consideration, as being worthy of imitation in Dublin. The cost of procuring stones suitable for Macadamizing, rendered pavement there an absolute necessity. Dublin, on the contrary, possesses an unlimited supply of the finest stone produced in the world, admirably suited for every description of street repair, which can be delivered for Macadamizing purposes in any quantity. It is to be regretted that the mode of street repair carried out in Birmingham, has not been quoted as more suitable for Dublin than that practised in Liverpool.

The Macadamized streets of Birmingham rank amongst the first in England; and if we are to consider Grafton-street as a specimen of pavement on the Liverpool pattern, it is an expensive failure. It has been laid down not more than four or five years, and is in course of being taken up and re-set for the second time within the last twelve months.

If we are to be compelled to rattle over paved streets, then let them be composed of the best materials that can be obtained for the purpose. Such may be procured in abundance from the Greenstone quarries (when properly opened,) and the chippings may, with economy, be used for Macadamizing; thus preventing the importation of a decidedly inferior stone, and advantageously employing the labour of our population

where the taxation is raised, instead of expending our money on foreign labour.

Previous to commencing this paper, I wrote to the Chairman of the Committee having charge of the repair of the streets, the following letter:—

"TERENURE TERRACE, ROUNDTOWN,
"*February* 21*st*, 1857.

"SIR,

"May I request you will be good enough to allow a list of the streets, lanes, and alleys, repaired by the Corporation of the City of Dublin, to be forwarded to me, distinguishing those that are paved from those that are Macadamized; together with the mileage of each separately.

"I wish the information for a paper I intend to read before the Institution of Civil Engineers of Ireland, on the economy of repairing and scavenging the streets of Dublin, compared with that of those of Lambeth, in London. Any cost that may be incurred in writing out the list, shall be paid by,

"Your very obedient Servant,

"R. H. FRITH.

"*To the Chairman of No.* 1 *Committee, City-Hall.*"

Not having received a reply, on the 14th of March I again wrote as follows:—

"TERENURE TERRACE, ROUNDTOWN,
"*March* 14*th*, 1857.

"SIR,

"On the 21st ult., I addressed a letter to the Chairman of Committee No 1, a copy of which is herewith sent. May I request you will be kind enough to inform me if it be your intention to allow the information therein set forth, to be forwarded. An early reply will oblige

"Your very obedient Servant,

"R. H. FRITH.

"*To the Chairman of No.* 1 *Committee, City-Hall.*"

On the 20th of March, not having received any acknowledgment of my former communications, I wrote to the Editor of *Saunders' News Letter*,—

"TERENURE TERRACE, ROUNDTOWN,
"20*th March*, 1857.

"SIR,

"The enclosed are copies of letters four weeks since addressed to the Chairman of the Committee having charge of the repairs and scavenging of the streets of the City of Dublin, and to which I have received no reply. May I request the favour of your publishing them, in order that the citizens may judge whether the suppression of the information therein requested, is likely to aid in the reduction of their taxation.

"I have the honour to be, Sir, &c.,

"R. H. FRITH, C.E., *County Surveyor*."

Which brought the following prompt reply from the Secretary:—

"CORPORATION OF DUBLIN, SECRETARY'S OFFICE,
"CITY-HALL, COMMITTEE No. 1,
"*Dublin*, 21*st day of March*, 1857.

"SIR,

"I am directed by this Committee to acknowledge the receipt of your letter, and to state that the matter referred to therein is under their consideration.

"Your obedient Servant,

"J. REILLY, *Secretary*.

"R. H. FRITH, Esq., *Terenure Terrace, Roundtown*."

As those gentlemen are, I suppose, still considering the matter, possibly in connexion with the improvement of the Dublin streets, I presume the reply will arrive when the streets shall have been freed from mud and made passable.

This course of suppressing official information pursued by gentlemen of the Corporation of Dublin towards a Member of this Institution, contrasts unfavourably for *them* with the facility given to me in London, in procuring the Lambeth schedule of prices, which I subjoin for *their* information:—

Road Materials, &c.,

To be delivered in the Bishop's, Prince's, and Marsh and Wall Wards.

	£	s.	d.
Guernsey broken granite (bird's-eye) at per cubic yard, .	0	15	4
New 2½-inch Eland edge York paving, full thickness, to be quarry measure, at per hundred feet superficial, . .	2	10	0
„ 3-inch York paving, full thickness, ...	2	18	0
„ 1st class rock-hill stone, long lengths, with sawn joints, at per foot superficial, ...	0	0	8
„ 2nd class do. do. do.,	0	0	7
„ 4-inch round sorrel pitching, at per ton, ...	1	6	0
(To be delivered to the Outworks, Nos. 1 and 2)			
Guernsey broken granite (bird's-eye) at per cubic yard, .	0	15	6
(To be delivered alongside any Wharf, as ordered.)			
Guernsey broken granite (bird's-eye) at per cubic yard, .	0	14	3
New 12-inch by 6-inch Aberdeen granite, edge kerb, at per foot run, ...	0	1	2
„ 12-inch by 6-inch circular do. do., .	0	1	3
„ 12-inch by 6-inch flat do. do., .	0	1	3
„ 12-inch by 8-inch flat do. do., .	0	1	6
„ 12-inch by 8-inch circular do. do., .	0	1	7
Purbeck edge kerb, not less than 10 inches by 6 inches, in lengths of not less than 2 feet 3 inches, and ends dressed square to not less than 8 inches deep, do., ...	0	0	7¾
New 12-inch by 6-inch Penryn granite, edge kerb, do., .	0	1	0
„ 12-inch by 6 inch flat do. do., .	0	1	0
„ 12-inch by 8-inch flat do. do., .	0	1	4
„ Circular do. do., .	0	1	5
„ Aberdeen granite cubes, at per ton, ...	1	3	0
„ 4-inch by 7-inch do. do., ...	1	6	0
Mason's and Paver's work, to supply and lay in any part of the parish.			
„ 12-inch by 6-inch Aberdeen granite, edge kerb, at per foot run, ...	0	1	4
„ 12-inch by 6-inch circular do. do., .	0	1	5
„ 12-inch by 6 inch flat do. do., .	0	1	5
„ 12-inch by 8-inch flat do. do., .	0	1	8
„ 12-inch by 8-inch circular do. do., .	0	1	9

	£	s.	d.
New Purbeck edge kerb, not less than 10 inches by 6 inches, in lengths of not less than 2 feet 3 inches, and ends dressed square to not less than 8 inches deep, per foot run, .	0	0	9½
„ 12-inch by 6-inch Penryn granite, edge kerb, do., .	0	1	2
„ 12-inch by 6-inch circular do. do., .	0	1	3
„ 12-inch by 6-inch flat do. do., .	0	1	3
„ 12-inch by 8-inch flat do. do., .	0	1	6
„ Circular do. do., .	0	1	7
„ 3-inch by 9-inch Aberdeen granite cubes, grouted with sand and lime, at per yard superficial, . . .	0	15	6
„ 4-inch by 7-inch do. cubes, do., . . .	0	11	0
„ 4-inch by 4-inch Mount-Sorrel pitching, do., . . .	0	7	0
Concrete, 6 inches thick, do., . . .	0	2	0
New 4-inch by 7-inch Aberdeen granite cubes, dressed for crossings, do., . . .	0	14	0
„ 2½-inch Eland edge York paving, full thickness, at per foot superficial, ...	0	0	7
„ 3-inch do. do. do., .	0	0	8
First-class rock-hill stone, long lengths, with sawn joints, at per foot superficial, ...	0	0	8½
Second-class do. do. do., .	0	0	7½
Taking up and relaying carriage-way pavements, grouted with sand and lime, at per yard superficial, ...	0	0	9
Taking up and relaying carriage-way pavement, laid with gravel, do., ...	0	0	7
Taking up and relaying kerb, at per foot run, . . .	0	0	1
Taking up and relaying and squaring old paving, at per foot superficial, ...	0	0	1¼

The taxation of Dublin for the present partial scavenging and repair costs £26,800 per annum. This by no means represents the cost paid by the citizens, as each householder is obliged to have the path swept before his door. The City contained, in 1851, 24,317 houses; we may expect that the number has not since decreased; and taking that as the present number, at 1d. per house per week for sweeping, amounts to £5,066, which, added to £26,800, makes £31,866, the annual amount paid by the citizens for scavenging, repairing, and watering the streets of Dublin.

It is impossible to have good roads without good scavenging, and from the neglect of scavenging comes the expensive, disgusting, and unhealthy practice of bucketing up in the streets during the day the contents of the sewers. The cavity formed by the disgorging operation is quickly filled in by the inexhaustible supply from above, which, during rain, is liquified and carried into the Liffey, accompanied by the animal matter contained in the cesspools through which it passes, and is afterwards deposited on either side of the river, where it lies exposed to the influence of the atmosphere, a decomposed and putrid mass, emitting an intolerable stench, and poisoning not only the atmosphere of the quays, but that of the houses, shortening the lives of the inhabitants, and seriously depreciating the value of the adjoining property—all which evils are traceable to defective management and scavenging.

Were it only for economy the mud should be removed from the surface of the streets, in preference to the present mode of diving after it into the City sewers and river. So long as this practice exists, whilst contagion is fostered on the streets, in the sewers, and river, vain will be the skill and exertions of physicians in the removal of disease; their labours, like those of Sisyphus, will be fruitless and interminable.

The length of the Dublin streets, according to civic authority, is 108 miles, in which measurement I by no means concur, as the City boundary, for upwards of three and a-half miles, passes along the centre of roads, one-half of which are in the County of Dublin, although generally repaired by the City.

It appears to me that the money paid by the citizens for road repairs should be confined to the repairing of those within their jurisdiction, particularly as the greater portion of this reputed length is not more than half repaired, many of the streets in the North-Eastern suburbs of the City being scarcely passable, and some of the leading thoroughfares in a rutty condition, and plentifully coated with mud. The expenditure

on the streets during the past year amounted to £26,800, being at the rate of £248 per mile per annum. The rates of labour and prices paid for material in Dublin and Lambeth respectively, are in—

DUBLIN	LAMBETH
Labour, . . 1s. 6d.	3s. 0d. per day, being 100 per cent. over Dublin.
Man and horse, 5s. 0d.	8s. 6d. ,, 70 ,, ,,
Broken stone per ton, 6s. 2d.—7s. per cubic yard.	15s. 6d. per c. yd., being 121 ,, ,,

With these prices, which are over 100 per cent. more than Dublin prices, the Lambeth vestry creditably maintained and scavenged 86 miles of streets, bearing at least fifty per cent. heavier traffic than those of Dublin, for £24,000, or £279 per mile per annum. Had Lambeth labour and material at Dublin prices, the work which costs there £279 per mile could be executed for £133 per mile. Yet, with all the advantages possessed by the City of Dublin for repairing and scavenging streets, they are the only roadways in Ireland destitute of progressive improvement. How is this? Are they beyond the reach of engineering skill? That they are not, without fear of contradiction, I unhesitatingly assert.

Six years having passed without improvement in the City streets, some other more advantageous method should be adopted for their management. It is but a lame excuse that the Corporation have not power to give contracts for more than three years. Parliamentary authority might easily be obtained to remedy this law; and the saving in one year's cost of maintenance would cover the expense of obtaining an Act for that purpose.

From the present condition of the streets it is not to be expected that the City could bear the taxation required promptly

to put them in repair. To attain this desirable end, I would suggest, as the most judicious mode, that the repair and scavenging of the streets be let, under a practical working specification, for a period of seven years, at a sum not exceeding £26,000 per annum. At the expiration of this contract, should it have been efficiently fulfilled, the after maintenance of the streets could be executed in contracts of three or five years, for £14,364 per annum, being the proportion that labour and material procurable in Dublin bear to those of Lambeth; but the streets of Dublin having been originally badly formed and bottomed, I would be disposed to add 25 per cent. to £14,364; this amounts to £17,955, for which they could be efficiently maintained. This would effect a saving of £8,845 per annum, a sum sufficient to warrant a change from the present defective and expensive plan of working.

[28th April, 1857.]

M. B. MULLINS, Esq., Vice-President, in the Chair.

THE discussion upon the paper by R. H. Frith, Esq., Member, "On the Comparative Cost of Street Maintenance in Dublin and at Lambeth, London," being resumed, was continued throughout the meeting.

[11th May, 1857.]

G. W. HEMANS, Esq., President, in the Chair.

On Beams *and* Girder Bridges.—By William Anderson, Esq., Associate.

The great diversity of opinion that has prevailed with regard to the proportions of the several parts composing a girder, has induced me to bring the subject of Beams and Girder Bridges before the Members of this Institution, in the hope that my remarks will provoke discussions, during which more facts, more theories, as to the real nature of strains developed in girders under different conditions, will be elicited.

Deeply sensible of my own unfitness to conduct the inquiries I have undertaken, I throw myself upon the kindness of the Institution, begging its members to remember that it is I who am seeking information, not presuming to offer it.

I will endeavour, as much as possible, to arrange the subject in proper order for rigid scrutiny; first determining the magnitude and direction of forces brought into play, and then proceeding to suggest the best means of counteracting them.

In all girders, of whatever form, we have three important parts; the top and bottom flanges, and the web or medium by which they are united. Confining ourselves to horizontal girders, with vertical forces acting on them, we have to consider the varieties of load as distributed, concentrated, or moving, placed on the top, or hung on the bottom flange, and under these several conditions trace the strains on the three component parts of a girder.

The first and simplest condition obtains when the load is at the centre of a girder, supported at each end as in figure 1, when A B = W represents the load, and C and D the supports. If a support were introduced at any point x, and the weight

relieved by it from the nearest abutment C, the pressure on x would be expressed—

$$\text{Pressure on } x = \frac{Wl}{2S} = P.$$

Where l = span, S = distance of x from D.

If $S = \frac{l}{2}$, pressure $= P = W$.

If $S = l$, $\quad P = \frac{W}{2}$

From this equation it is evident that vertical lines drawn from the beam to the right lines A F and A E will correctly represent the vertical pressure at any part if F C = ½ A B.

It needs no illustration to demonstrate that the same load travelling from end to end would successively produce a vertical pressure equal to itself, and that a line parallel to the beam through the point A, would represent geometrically its maximum effect at any point.

It is equally evident that with the weight W uniformly distributed, the support x would have to sustain half the weight of each section of the load $\frac{W' + W''}{2} = \frac{W}{2}$. W′ and W″ being the value of the respective sections of the load acting at their centres of gravity, and in this case also a line parallel to the beam with A B $= \frac{W}{2}$ will define the vertical pressure at any point.—(See fig. 2.)

When a beam is in a state of equilibrium, however loaded, the point x is supported by the resistance which the upper flange offers to compression, and the lower to extension. The load produces a reaction on each of the piers supporting it, in inverse ratio of its distance from either pier, and this skeleton diagram will illustrate precisely the state of the forces induced. (See fig. 3.)

d represents the depth of beam, S the distance of x from the

pier, C the compressing force on the upper flange, and E the extending one on the lower.

$$\text{Therefore } P'S = Cd' + Ed''.$$

C, however, must be equal to E, or positive tendency would exist to move in the direction of the larger force, which is not the case, so that

$$P'S = C\,(d' + d'') = Cd = Ed.$$

$$\text{Therefore } E = C = \frac{P'S}{d}$$

Now for a beam loaded at the centre only, from fig. 1 it will be seen that the reaction P′ on the pier from a force P at any point x, may thus be deduced:—

$$P = \frac{Wl}{2S}$$

Taking the moments of P′ and P round the end D, $PS = P'l$

$$\therefore P' = \frac{PS}{l}$$

$$\therefore P' = \frac{Wl}{2S} \times \frac{S}{l}$$

$$\therefore P' = \frac{W}{2}$$

Substituting this value we have

$$E = \frac{W}{2} \times \frac{S}{d} = \frac{WS}{2d}$$

$$\text{If } S = \frac{l}{2} \text{ then } E = \frac{Wl}{4d} = \text{strain at centre of flanges.}$$

Also $S' = O$, $E = O$, so that straight lines from the ends of the beam to the line of greatest strain at the centre would define geometrically the tension on any part of the flange.

Again it has been shown that a uniformly distributed load W produces a vertical pressure of $\frac{W}{2}$ at any point x (fig. 2), and the reaction of this pressure on the piers.

$$P' = \frac{W S}{2 l}$$

$$\text{But } E = \frac{P' S'}{d} = \frac{W S}{2 l} \times \frac{S'}{d} = \frac{W S S'}{2 l d} = \frac{W S (l - S)}{2 l d}$$

$$\text{Let } S = O, \text{ then } E = O$$

Let $S = S' = \frac{l}{2}$ then $E = \frac{W l}{8 d}$ the familiar equation for strain produced at centre of flanges by a uniformly distributed load. (See fig. 4.)

Let a be the sectional area in square inches of a wrought iron flange, then a 20 tons will be its ultimate strength, if we assume 20 tons per square inch as the average tensile strength of wrought iron—then

$$E = \frac{W l}{8 d} = a\, 20$$

$\therefore W = \frac{160\, a\, d}{l}$ = breaking weight uniformly distributed, or $\frac{W}{2} = \frac{80\, a\, d}{l}$ for the breaking weight in the centre. This is the formula deduced from the experiments made during the progress of the Britannia and Conway tubular bridges.

Up to this point we have altogether neglected to inquire into the forces developed in the vertical faces or webs; it is necessary now to examine what these are, and to observe how they affect the equations we have obtained. It is clear that the two vertical and opposite pressures—namely, the load and the reaction of the piers cannot produce the horizontal forces in the flanges, without some sort of diagonal strain passing through the web.—(See fig. 5.)

Thus, if C O (fig. 5) represent the load hung in the centre of the beam A B, and C K = E represent the strain in the bottom flange due to that load, then because only one-half of W is producing the strain K C (the other half straining the top flange to an equal extent), the resultant C M of the forces

$\frac{W}{2}$ and E should represent in magnitude and direction the the strain in the web. Producing C M to its intersection at L with the top flange, and dropping the vertical line L B, we have Δ L C B similar to Δ C K M, and therefore

$$KC : KM = BC : BL$$

$$\text{or } E : \frac{W}{2} = BC : d$$

$$\therefore BC = \frac{2Ed}{W}, \text{ but } E = \frac{Wl}{4d}$$

$\therefore BC = \frac{l}{2}$; in other words, the strain will be carried in a direct line to the pier by tension through the web. Similarly we may suppose half of W is carried vertically through the web to the top flange, and then by similar reasoning a resultant may be found transmitting a thrust to the pier at B. It is hardly necessary to show how, assuming that the strains do actually pass as explained above, the formula $E = \frac{Wl}{4d}$ may be obtained. We have seen

$$E : \frac{W}{2} = \frac{l}{2} : d$$

$$\therefore E = \frac{Wl}{4d}$$

Also in a uniformly loaded beam it has been shown that the vertical pressure at any point is $\frac{W}{2}$, consequently the strain E is produced by one-fourth of W only, and the proportion above would stand

$$E : \frac{W}{4} = \frac{l}{2} : d$$

Whence $E = \frac{Wl}{8d}$ as already obtained.

Now the forces C L and R B being opposite in direction,

and in most cases at an acute angle to each other, would doubtless neutralize one another to a certain extent—would produce in fact resultants at right angles to each other, and at an inclination of 45° to the flanges. That this actually takes place we have abundant evidence in Edwin Clark's description of the experiments made on the large model of the Britannia Tube. We have to regret, however, that no drawings have been published of the injured sides, so that the student of these magnificent experiments must trust more to Mr. Clark's description and to his own imagination, than is altogether safe. Had photography reached its present state of perfection in those days, what an invaluable record we might have had of these costly investigations! I have pointed out how the strains in the plate sides of a beam may interfere with each other, and the suggestion naturally presents itself of transmitting these strains through independent channels, expressly adapted to withstand the peculiar nature of the force. This indeed has been most successfully done; the consideration of that important achievement, however, cannot be included in the limits of this paper, I must therefore crave permission once again to trespass on your patience at some future meeting.

[16th March, 1858.]

M. B. MULLINS, Esq., Vice-President, in the Chair.

On BEAMS *and* GIRDER BRIDGES (Part 2).—By WILLIAM ANDERSON, Esq., Associate.

In the paper I had the honour of reading in this Institution last session, I endeavoured to ascertain the magnitude and direction of forces acting on the chords or flanges of beams, and concluded it by showing that diagonal forces, difficult to define, must be in operation in their vertical portions or webs,

and stated that these diagonal strains might be turned into certain channels, where their magnitude might be measured, and directions varied at will. My immediate object this evening will be to examine the properties of diagonally braced beams.

The trussed beam represented in fig. 6 is very commonly employed by carpenters for spanning considerable openings, and is perhaps the simplest form of girder, and therefore best suited to exhibit the nature of the arguments I propose to use. The essential portions of the beam are A C D B, also the vertical bars C E and D F, when the load is placed on the bottom flange; l is the span, and $AE = EF = FB = \frac{l}{n}$. Let us suppose a load W to be uniformly distributed along the top of the beam, in which case those portions of the flanges between the supports, which must be quite rigid, would act as short beams, and carry half of the load resting on them to each of their extremities. In this way the point C would have to carry half the weight on L C, and half on C D, equal together to $\frac{W}{3}$, which would pass down to the pier along the diagonal C A, leaving a resultant C D to be balanced by the similar distribution of forces due to the resolution of $\frac{W}{3}$ through D B and D C. The strain on C A would bear the same proportion to $\frac{W}{3}$ that its length does to d.

$$\therefore \text{ strain on } CA = \frac{Wa}{3d} = \frac{W}{3d}\sqrt{\frac{l^2}{n^2} + d^2}.$$

The strain E on the flanges also would be as much greater than $\frac{W}{3}$ as A E is longer than d, so that $E = \frac{Wl}{3 \times 3 \times d} = \frac{Wl}{9d}$ or generally $E = \frac{Wl}{n^2 d}$. Now the formula obtained in the earlier

part of this paper made $E = \frac{W l}{8 d}$ for a plate beam, or greater by $\frac{W l}{72 d}$, which is easily explained when we consider that the load is virtually concentrated, by the innate stiffness of the flanges, at C and D, and so rendered incapable of producing its full effect, just like what would be the result of placing a stiff beam of one-third the length along the middle of a plate beam, thereby relieving the weight off the centre.

If, however, a beam of this kind be loaded unevenly, say by a weight concentrated at C, the resultant along C D meets with no equal and opposite force, and the beam will consequently collapse sideways; by introducing a diagonal E D, however, this may be remedied; for, supposing the weight on C to be 16 tons, $l = 24'$, $d = 3'$, and $a = 8{\cdot}54$, we have the following result:—

The 16 tons at C is carried by the two piers A and B in inverse ratio of this distance from C, that is, as 2 : 1, A carries 10·66, B carries 5·33, and these pressures must travel from C along the diagonals and flanges, so that strain on A C : 10·66 = 8·54 : 3.

$$\therefore \text{ strain on A C} = 30{\cdot}3 \text{ tons.}$$

$$\text{Strain on C D} : 10{\cdot}66 = 8 : 3 = 28{\cdot}4 \text{ tons.}$$

The reaction of the pier B, when resolved along B D and D C will only yield half these strains, as well as an unbalanced upward force of 5·3 tons at D. But if the pressure of 15·15 tons along D B be resolved along C D and E D, the balance is immediately restored; for then

$$\text{Strain on C D} : 15{\cdot}15 = 16 : 8{\cdot}54.$$

Strain on C D = 28·4 tons, equal to that from C to D. While a tension of 15·5 tons acts along the diagonal D E. By introducing a corresponding diagonal from C to F, the beam is made secure for any kind of load. This arrangement, however, labours under the disadvantage of having the most

severely strained parts in a state of compression, and therefore of unstable equilibrium. By turning the beam upside down, this may be corrected, and the diagonals L E, M F (fig. 7) brought into a state of tension. A combination of these two varieties, shown by fig. 8, will at once be recognized by those who remember the Exhibition of 1853. The beams used in that building were tested by Mr. Fairbairn, at Mr. Dargan's request, and alterations suggested in consequence—the wisdom of which I am inclined to question. A load of 32 tons was laid on, principally between the uprights C and D; a deflection of 1·6 inches was obtained, the bars A C and D B, being so much bent and puckered that it was considered unsafe to continue the experiment. Mr. Fairbairn, in commenting on the behaviour of the beam, very justly recommends T or L iron for the struts A C and D B, but counsels the entire removal of the middle diagonals, which were found to be perfectly slack, and the substitution of a vertical strut in the centre; whereas, by what we have seen, it is evident that had the load been moved a little nearer either end of the beam, one of the middle diagonals would at once have come into play. The proportions of these beams are represented in fig. 8, so that

$$\text{Strains on A C and L E} : 16 \text{ tons} = 8{\cdot}54 : 3.$$

$$\therefore \text{ Strains on A C and L E} = \frac{16 \times 8{\cdot}54}{3} = 45{\cdot}5 \text{ tons.}$$

$$\text{Strains on C D or E F} : 16 \text{ tons} = 8 : 3 = 42{\cdot}7 \text{ tons.}$$

Now the lattice bars were $3'' \times \frac{1}{2}''$, giving, after deducting a $\frac{3}{4}$ inch rivet hole, a sectional area of 1·12 square inches each; and supposing the strains to have passed along them in equal portions, it follows that this must have been at the rate of 20·3 tons to the square inch, so that the bars L E and F M must have been very nearly on the point of rupture, especially as the buckling of the struts C A and D B probably threw more weight on them still. The bottom flange was composed of

two bars of $3'' \times 3'' \times \frac{1}{4}$ L iron, the area of which, exclusive of a $\frac{3}{4}$ inch rivet hole in each, would be $2\frac{1}{2}$ square inches, strained, as we have seen, by a force of 42·7 tons, or at the rate of 17 tons per square inch. The top flange was composed of $3'' \times 3'' \times \frac{3}{8}$ L iron, with an area, including rivet holes, of 4·3 square inches, bearing a pressure of 10 tons to the inch. It is manifest, therefore, that the beam would have failed in the lattice work, and not in the flanges, consequently Mr. Fairbairn commits an error in adapting the formula $W = \frac{adc}{l}$ to lattice beams, by diminishing the constant C from 80 to 72, so as to give a larger sectional area to the flanges, whereas increasing the strength of the flanges would not have made the beam any stronger.

The vertical strut in the centre would give only as much support to the load as the innate stiffness of the bottom flange, considered as a beam, could afford, which would be insignificant, whereas the cross strain thrown on a chord in violent tension would certainly be injurious.

I have dwelt thus minutely on this subject, because I have seen so many designs for girders, in which the lattice work was left of the same scantling for beams of different strength, the designers fancying that it was only necessary to augment the size of the flanges, in order to increase the strength of the beam to the same extent. Mr. Fairbairn also calls the trellis beam "an imperfect double flanged beam," which I cannot allow, except, as in the case of the Exhibition girders, the lattice work is improperly proportioned to the strength of the flanges, in other respects it is well known, and will presently be demonstrated, that lattice beams do not require larger flanges than plate beams. The shorter a column under compression is, the less liable will it be to yield, while the length of a bar in tension does not affect its strength; so one object to be aimed at in arranging the lattice work of a beam

is to keep the struts as short as possible. This may be attained in the following arrangement. The element 2 1 1 2 of the beam in fig. 9 is the same as in fig. 7, the property of which we have already investigated, but its ends, instead of being supported by a pier, rest on the struts 2 2 of a larger external beam; this again is supported by the ties 3 2 2 3 of a still longer beam resting on the struts 3 3, and so on till the piers are reached. Supposing the beam to be uniformly loaded, the struts 1 1 will support $\frac{W}{n}$ each, and the strains on diagonals 1 2 : $\frac{W}{n} = a : d$.

$\therefore$ Strains on diagonals $= \frac{W a}{n d}$. When the strain reaches 2 it resolves itself horizontally through 2 1, and vertically through 2 2, passing down 2 2, together with the portions of the load immediately over $2 = \frac{W}{n}$, so that $\frac{2 W}{n}$ are resolved along the diagonal 2 3 and $2\ 1 = \frac{2 W a}{n d}$. In this manner 3 4 carries $\frac{3 W a}{n d}$ and the diagonal at 5 6 bears $\frac{5 W a}{n d}$, the strains increasing in arithmetical progression, so that the last strut would have to carry $\frac{6 W}{n} + \frac{W}{2 n} = \frac{13 W}{2 n}$, but as n in this case is 13, the pressure on the pier would be $\frac{W}{2}$, a self-evident fact. In the next place, the strains on the flanges may easily be determined. The load on $1\ 1 = \frac{W}{n}$, resolved through 2 1, and the middle part of flange, and

$$\frac{W}{n} : \text{strain E} = d : \frac{l}{n} \therefore \text{strain E} = \frac{W l}{n^2 d}.$$

The strain at 2 similarly will be $\frac{2 W l}{n^2 d}$, and so on for each section of the beam.

Now, from the view originally taken of these forces, it would follow that the resolved strain at 7 passes through the entire length of the beam; so also the strain due to 6, and the rest; consequently, as the centre is approached, each section of the flange has to resist a strain augmented by decreasing increments.

$E = \frac{6\,W\,l}{n^2\,d} + \frac{5\,W\,l}{n^2\,d} + \&c. + \frac{W\,l}{n^2\,d}$. The series having 6 terms its sum would be

$$E = \frac{7\,W\,l}{n^2\,d} \times 3 = \frac{21\,W\,l}{n^2\,d}; \quad \text{but } n = 13.$$

$\therefore E = \frac{W\,l}{8{\cdot}04\,d}$, which, practically, is the identical formula obtained in the early part of this paper by totally different arguments, the discrepancy being accounted for as already pointed out by the peculiar arrangements at the centre of the beam.

The advantage of this form of trussed girder, I have already mentioned, lies in the compressed bars being the shortest possible, and therefore less liable to yield for want of lateral support. A very interesting example of the application of this system to practice may be found in the foot-bridge over the Dublin and Drogheda Railway at Drogheda, constructed, according to designs by Mr. Harty, the Company's engineer, through whose kindness I am enabled to exhibit a model made by himself, exactly to scale, and provided with weights, the application of which shows the nature of the strains on the several parts. This bridge is 54 feet span, and notwithstanding the extreme lightness of lattice work, is remarkably stiff.

The girders supporting the curved roof of the Art Treasures Exhibition at Manchester were also of this class.

If the two diagonal struts in fig. 6 be approached towards each other, till they coincide at their upper extremities, a

considerable alteration will take place in the distribution of forces. The beam has been divided into two sections, and half the load on each is carried by the apex C of the triangle C A B (fig. 10). The resolution at that point takes place immediately along the two struts, and the reaction of the piers creates a tensile strain in the lower flange A B.

$$\text{Strain on A C}: \frac{W}{2} = \frac{a}{2} : d.$$

$$\text{Strain on A C} = \frac{W\,a}{4\,d}.$$

$$\text{Strain on A B}: \frac{W\,a}{4\,d} = \frac{l}{2} : a.$$

$E = \frac{W\,l}{8\,d}$ the formula previously obtained, and perfect in this instance, because a load is truly carried all through by the beam itself.

Supposing now this system were extended, and the triangle A C B, instead of resting on piers, were to be suspended from two tension bars E A and D B, E and D being kept apart by a flange, and supported by two struts E F and D H, tied by means of a flange F H. With a uniform load the weight on C would be $\frac{W}{n}$, the strain on A C, C B, would be $\frac{W\,a}{2\,n\,d}$ which would be carried by A E to the point E, when it would resolve into a pressure through the flange, and a vertical force of $\frac{W}{2\,n}$. The weight resting on E is $\frac{W}{2\,n}$, or half that distributed between F and C, and $\frac{W}{4\,n}$, or half that between X and E, equal together to $\frac{3\,W}{4\,n}$; the strut E F, therefore, would have to carry $\left\{\frac{3\,W}{4\,n} + \frac{W}{2\,n}\right\} \frac{a}{d} = \frac{5\,W\,a}{4\,n\,d}$, and this would be resolved into tension of the bottom flange, and the vertical reaction of

the pier equal $\frac{3\,W}{4\,n}$, to which must be added the portion of $\frac{W}{2\,n}$ supported by the vertical strut F L$=\frac{W}{4\,n}$, so the total pressure on the pier will be $\frac{5\,W}{4\,n}+\frac{W}{4\,n}=\frac{6\,W}{4\,n}$, but $n=3$.

$\therefore$ Pressure on pier$=\frac{6\,W}{12}=\frac{W}{2}$, or half the load, which is evidently true.

Again, the thrust of E F produces tension in the bottom flange, and E : $\frac{5\,W}{4\,n}=\frac{l}{2\,n}:d$.

$$\therefore\ E=\frac{5\,W\,l}{8\,n^2\,d}.$$

The tension on A B due to the portion of the load on C : $\frac{W}{n}=\frac{l}{2\,n}:d=\frac{W\,l}{2\,n^2\,d}$, so that the entire strain on A B will be expressed

$$E=\frac{5\,W\,l}{8\,n^2\,d}+\frac{W\,l}{2\,n^2\,d}=\frac{9\,W\,l}{8\,n^2\,d}$$

Now $n=3$, $n^2=9$; and $E=\frac{W\,l}{8\,d}$, demonstrating the accuracy of the argument.

By reversing the arrangement in fig. 10, we have the load carried to the piers by tension rods, in place of the struts E F and D B; in that case the two bars A C, C B are unnecessary where the beam is loaded uniformly and on the top. By combining these two arrangements, we have the familiar form of lattice beam, as in figs. 11 and 12.

I have shown, at each step of these investigations, how the formula $E=\frac{W\,l}{8\,d}$ may be obtained by resolving the forces through the vertical web or sides of beams; and I would now draw your attention to some diagrams, which will show still

more clearly how each line of argument confirms the other. The beams represented in figs. 11 and 12 are 42 feet span, 3 feet deep, loaded with a ton for each running foot. The uniform parabolic line underneath them shows the strain on the flanges of a plate beam, calculated by the formula $E = \frac{WS(l-S)}{2ld}$ while the short horizontal lines indicate the strain on the flanges, calculated by the method just described. One marked difference is at once apparent. The strain does not increase gradually towards the centre, but by sudden increments, at the junction of each lattice bar with the flanges, but still it will be seen that the parabolic line is the average of such increments. The closer the lattice work is, the more nearly does it resemble a plate beam, each additional set of lattice bars forming a complete system, taking upon itself a portion of the strain upon the former bars, as shown in fig. 7. On comparing figs. 11 and 12, where the latter has double the number of lattices, it will be seen that the strain on each of the original bars is reduced one-half, and it is not difficult to conceive that the number of bars may be increased till their edges coincide, and two continuous plates be formed.—(See fig. 13.)

To illustrate this view more clearly, let us suppose the lattice bars in fig. 11 increased very much in breadth, which shall be constant all through, the necessary increase in strength towards the ends being obtained by increased thickness. I should also mention here, that although the investigations we have been following were quite general, and irrespective of any peculiar slope in the lattice bars, yet the figures are all constructed for an angle of 45°, which, as shown in the former portion of this paper, seems to be the angle in which the strains naturally run.

Now if the width of the lattice bar be increased to $\frac{a}{2}$, or half

its length, we will have the two systems of lattices filling up the entire side, making, in fact, a continuous web, as represented in fig. 13, where the lined and dotted bands illustrate the arrangement in question. At the intersection of these bars, a double thickness may be avoided by supposing them cut out of a solid plate, so that each bar, though compressed in one direction, would be extended by the forces due to the transverse bar, which probably would not affect its powers of resistance either way. The thickness of *wrought iron* plate that would suffice to bear the compression of the dotted band resting on the pier, would amply suffice to carry the tensile strain of the lined band, and conversely, in cast iron, what would be strong enough to resist the tensile strain, would necessarily carry the compressive force, so that if the weaker power of any material be proportioned to the strain on the last diagonals, these being known, the thickness of the web may be computed.

The strain in the last diagonal, from what we have seen and illustrated by fig. 11 $=\frac{W a}{2 n d}\times 7$, 7 being the number of the lattice from the centre $=\frac{n}{2}$, the bars being at angles of 45° $n=\frac{l}{d}$

$$\therefore \text{Strain on last lattice}=\frac{W a}{2 n d}\times\frac{n}{2}=\frac{W a}{4 d}.$$

And this must equal the sectional area of the bar, multiplied by the pressure (p) per square inch, or the unit strain to which it is safe to subject the material. Let t = thickness $\therefore \frac{a t}{2}=$ area of bar, and $\frac{a t p}{2}$ = strain in tons it may carry, so that

$$\frac{W a}{4 d}=\frac{a t p}{2} \therefore t=\frac{W}{2 p d}$$

On reference to Edwin Clarke's work on the Britannia Bridge, page 346, it would appear that under the most favourable circumstances, namely, in rectangular tubes, buck-

ling of their sides under pressure began at from 6 to 9 tons per square inch, it would not therefore be safe to strain plates to more than 1-4th of 8 tons to the inch, or 2 tons, so that for wrought iron webs the formula becomes $p=2$, $t=\frac{W}{4\,d}$.

As far as I am aware, this formula is original, and I therefore beg the members of the Institution will receive it with caution, though, from examples which I will now adduce, I believe it to be practically accurate.

Firstly,—Let us examine the Conway Bridge, 400 feet span, 25 feet 5 inches deep in the centre, 22 feet 5 inches at the ends, sectional area of bottom flange at centre $=535$ square inches, side plates $\frac{5}{8}$ thick.

Supposing the bottom flange capable of resisting safely a strain of 5 tons per inch, $E=535\times5=2675$ tons.

$$\text{And } E=\frac{W\,l}{8\,d}\;\therefore\; W=\frac{8\,d\,E}{l}=\frac{8\times25\times2675}{400}=1337 \text{ tons.}$$

And $t=\frac{1337}{4\times22\times12}=1{\cdot}25$ inches, which is the exact thickness of the two sides together, not counting the vertical angle and T iron stiffening pieces, which were intended only to keep the plates in shape, and could not, from their position, resist much of the strain.

Secondly,—If we examine an experimental beam 66 feet span, 10 feet deep in the centre, and 6 feet at the ends, made by Mr. Brunel, and described by Edwin Clark, in his work on the Britannia Bridge, we will find the formula to agree very closely with actual results. The flanges were of triangular section, 18 inches deep, so that the web was virtually not more than $3\frac{1}{2}$ feet deep over the piers, and $\frac{1}{4}$ inch thick. A load of 165 tons near the centre tore the sides near one end through the rivet holes. Now for a load in the centre, $t=\frac{W}{p\,d}$; p, which in this case would be the ultimate strength

of plate iron may be taken at 24 tons to the square inch, and $d = \frac{2}{3} \times 42$ inches $= 28$ inches, to allow for rivet holes. The thickness of plate that would fail in this case would be $t = \frac{165}{24 \times 28} = 0{\cdot}24$ inches, which is within 0·01 of the actual thickness which failed (through a line of rivets).

Applying the formula to the 42 feet beam, 3 feet deep, loaded with 42 tons, we have $t = \frac{42}{4 \times 36 \times 1} = 0{\cdot}29$ inch, or a little over $\frac{1}{4}$ inch, which would be nearly the thickness I should have made it from experience. One other result seems to follow from this view of the matter. On reference to fig. 8 it will be seen that, to allow a full bearing to the broad lattice bars, the beam should rest for half its depth on the piers, or bearing on piers $= \frac{d}{2}$, and so we find that the Conway tube has 12 feet bearing, and is 22 feet 5 inches deep.

The same expression for the thickness of the sides may be arrived at by considering the upward reaction of the piers as a strain tending to shear off the end of the beam. Now the reaction of the pier is $\frac{W}{2}$, and the resistance to shear is the same as that to direct tensile strain; equating, therefore, $\frac{W}{2}$ to the area of sides multiplied into the strain per square inch the material can safely carry, we have

$$\frac{W}{2} = d\,t\,p$$

$$\therefore t = \frac{W}{2\,d\,p} \text{ as before.}$$

In this case it is assumed that the areas of flanges at the piers are 0. This argument is not so clear as that previously used; but it is satisfactory to find two distinct methods of investigation yield identical results.

I find that this interesting subject has carried me along, in spite of myself, further than I originally intended. I have trespassed on your time too long already, and yet but the first part of what I proposed to do has been accomplished. The strains have been ascertained and defined for uniformly loaded beams, easy practical formula obtained for the strains in the flanges and webs of plate and lattice girders, but we still have to consider the effect of passing loads, and how these strains may best be counteracted. I have then some observations to make on railway and road bridges, and beams for the support of floors and walls of buildings. I therefore propose, once more, to ask your kind attention on some future day; and in conclusion beg to acknowledge, gratefully, the assistance and advice I have frequently received from Mr. Harty, the engineer of the Dublin and Drogheda Railway, to whom we are indebted for the use of that model, and from Mr. Stoney, whose name is so well known in connexion with that magnificent monument to Irish engineering skill, enterprise, and industry—The Boyne Viaduct!

[11th May, 1858.]

M. B. MULLINS, Esq., in the Chair.

DESCRIPTION *of some* EXPERIMENTS *made at the* BOYNE VIADUCT *in* 1854.—By BINDON B. STONEY, Esq., Member.

A BRIEF description of the Boyne Viaduct and of the severe tests to which the iron work was subjected before being opened for public traffic was laid before the Institution of Civil Engineers, London, in April 1855, in a paper, "On the Economic Distribution of Materials in the Sides or Vertical Portion of Wrought Iron Beams," by James Barton, M. Inst. C. E.* In this paper, which gave rise to a prolonged and most interesting discussion, Mr. Barton, after some theoretical considerations respecting the direction of the strains in the vertical web of wrought iron girders, proceeds to institute a comparison between the different methods of construction adopted in this portion of a beam, and in conclusion gives a concise account of the more important structural features of the viaduct, without, however, describing in detail those experiments which were made during the progress of the work in order to test the strength of some of its component parts.

In bringing before your notice this evening some of these experiments, perhaps some apology may be due for framing a paper on such a slight basis, but my feeling on the subject is that—though few in number, yet from their unusual character, and from the importance of the results which, I believe, may be deduced from them—these experiments are of sufficient importance to make it desirable that they should become, as

* See vol. 14, *Proceedings of Inst. C. E.*

it were, public property, in place of being available alone by those who were present during their performance.

Pillar Experiment No. 1.

The essential difference between lattice and plate beams consists in the formation of the vertical web, that in the former being constructed of intersecting bars, while in the latter the web is one continuous plate. As neither thin bars nor plates are suitable for resisting compression, it has been found necessary to stiffen those parts which act as struts by means of angle or T irons, as in the Tubular bridges, or by means of angle irons, combined with internal bracing, as is now usual in lattice beams. The cross section of the Boyne Viaduct, which may be taken as a type of the most approved method of latticing at present adopted, is the same as that of the tubular girder, if we substitute intersecting bars for the continuous plate. The angle iron stiffeners of the tubular girder are generally placed vertically; in the class of bracing adopted in the viaduct they are at an angle of 45°, and the two opposite angle irons are, moreover, connected by diagonal bracing, which greatly increases their stiffness in a direction at right angles to the plane of the beam (see fig. 1). This kind of bracing is, it will be perceived, an application of that so familiar to us in the form of lofty scaffolding, and of which the piers of the Crumlin Viaduct present fine examples. As, however, its application to the compression bars of diagonally braced bridges was comparatively recent, and as no direct experiments on its utility in this respect had been made, or at least published, it was thought desirable to test by direct experiment whether this arrangement of bracing would enable a bar, thin in proportion to its length, to sustain an endlong pressure approaching to the crushing weight of the iron.

Accordingly, an experimental beam, similar to those used at the centre of the centre span of the viaduct, was constructed by Mr. Barton's directions. The first experimental beam resembled fig. 1 in every respect, except the lower portion, which was formed as shown in fig. 4. This pillar, which was 31′ 6″ in length, with $4'' \times \frac{5}{8}''$ side bars, was erected in the midst of some timber scaffolding which had been used for a hoist. The testing weight was suspended below the wooden framing on which the pillar stood by long suspension rods which were attached to a cross piece of timber resting on the top of the pillar (see figs. 2, 3.) By this arrangement the pressure was made to pass more accurately through the axis of the pillar than if the testing weight had been heaped up on top. It was also more convenient to load at the lower level. Cross bars were attached to the sides at the same intervals as the latticing in the viaduct, and were connected at the ends to the scaffolding, so as to act as the tension diagonals in the bridge; and here I may remark that the chief advantage of a multiple over a single system of triangulation consists in the more frequent support given by the tension bars to those in compression, as well as by both to the flanges. The parts in compression are in fact subdivided into short pillars, and thus prevented from deflecting. When a single system is adopted, as in 'Warren's' girder, each strut is unsupported throughout its length, and is therefore more liable to deflect than in a lattice beam. A cord was stretched vertically, in order to get the lateral deflections during the experiment. These were taken at three points, A, B, C (fig. 1); and the symbols + or — placed before a deflection in the table signifies that it was in the direction of the same sign in the figure.

DEFLECTIONS.

Date	Tons	A	B	C	Remarks
1854.		Inches	Inches	Inches	
Nov. 16,	0				
,,	5	+0·03	+0·05	+0·03	
,,	10	0·0	0·0	+0·05	
,,	15	—0·03	+0·03	+0·05	
,,	20	—0·05	0·0	0·0	
,,	25	—0·05	0·0	0 0	
,,	30	—0·05	—0·03	—0·04	
,,	37½	—0·06	—0 07	—0·06	
,,	40	—0 05	—0·01	—0·05	With 40 tons the side bar at (*a*), fig. 4, bent slightly at right angles to the plane of figure.
,,	42½	—0·10	—0·10	—0·13	With 42½ tons the lower part of pillar at (*b b*) became slightly curved, with the convex side towards the — side.
Nov. 17,	42½	—0·10	—0·10	—0·13	Left on all night; no change in the morning.
,,	45	—0·10	—0·15	—0·16	
,,	47½	...	...	...	The side bars gave way, as shown in fig. 5.

N.B.—The deflection of B with 40 tons seems anomalous; probably a mistake for 0·10?

Looking at fig. 4, it will be seen that about 8 inches in length of each side bar near the ends of the pillar were left without angle iron, and when the weight amounted to 47½ tons this part yielded sideways, as shown in fig. 5.

The area of the two bars at the part which failed amounts to 5 square inches: the compressive strain which passed through them at the moment of yielding equalled, therefore, 9½ tons per inch.

Experiment No. 2.

The pillar in the first experiment failed, as indeed had been anticipated, by the upper part moving sideways past the lower, as if connected to it by hinges. The pillar was taken down, the injured part removed, and the length thus reduced to 28′ 6″. The repaired pillar, fig. 1, was then replaced in the

frame, and the following table contains the observations recorded, which include the contraction in length of each side under the compressive strain. These latter observations were made by the aid of wooden rods suspended at each side from near the top of the pillar. Each rod was 24′ 8½″ in length from the point of suspension to the index at the lower end, and it will be observed that the contraction of one side exceeds that of the other in a very anomalous manner, which can only be explained by supposing that the timber framing yielded more beneath one side than the other, and thus caused a greater strain of compression to pass through that side which contracted most. It is also probable that the centre joint on the — side was not a perfect butt joint, and thus a slight movement might take place from the ends coming into close contact.

Date	Tons	A	B	C	Rod on + side	Rod on - side	Observations
		Inches	Inches	Inches	Inches	Inches	
Nov. 25,	0						
"	30	+0·03	+0·04	+0·01	0·05	0·25	At 30 tons the side bar at (c) bulged outwards slightly, with a tendency to increase; also a slight hollow was produced at (d); to remedy this bulging (which seemed to be caused by the unequal compression of the timber packing, that on the + side yielding more than the opposite), a strut was placed against (c), and the weight was blocked up until the 27th: wedges also were driven between the wooden packings underneath, in order to tighten them up.
Nov. 27,	0	...	...	...	0·0	0·20	Load removed, bulging at (c), removed, as nearly as possible, by means of a screw-jack which was left in position; opposite side similarly blocked out from staging, and blocks were placed at similar positions at top of pillar, as there appeared a tendency of top to move over to — side.
"	30	...	...	...	0·05	0·25	
"	35	...	...	...	0·06	0·27	
"	40	0·0	—0·01	—0·03	0·08	0·31	Left hanging all night, wind so strong as to make deflections uncertain.
Nov. 28,	40	0·0	—0·37	—0·07	0·09	0·31	The hollow at (d) still well marked, and a tendency to deflect towards + side, at the centre of pillar.

TABLE—*continued.*

Date	Tons	A	B	C	Rod on + side	Rod on — side	OBSERVATIONS
		Inches	Inches	Inches	Inches	Inches	
Nov. 28,	45	0·0	—0·01	—0·07	·09	·34	Wind in gusts; 45 tons left hanging one hour.
,,	50	+0·07	+0·06	—0·03	·10	·40	Wind much abated; no visible change.
,,	55	...	...	...	·10	·44	Wind so strong as to prevent deflection being taken. No visible change.
,,	60	...	...	...	·10	·49	No change visible.
,,	62½	...	...	...	·105	·50	Left hanging on all night.
Nov. 29,	...	...	...	...	·11	·50	No visible change this morning.
,,	65	...	...	...	·12	·53	The buckle at centre strongly marked.
,,	70	+·15	+·14	+·03	·12	·56	Wind much abated.
,,	72½	...	...	...	·13	·60	
,,	75	...	...	...	·14	·65	No visible change or upsetting of any part.
,,	77½	...	...	...	·13	·69	
,,	80	...	...	...	...	...	Left hanging on all night.
Nov. 30,	...	...	...	...	·14	·78	In morning.
,,	82½	...	...	...	·15	·795	
,,	83½	...	...	...	...	...	Broke down as the additional ton was being laid on, parts (*b*) and (*e*) giving way. At (*e*) both sides of the pillar bent, and the internal lattice was completely distorted, the L iron being broken away from side bar, (see fig. 2).

The sectional area of the pillar subject to compression, and including the angle irons, is 7·5 inches. The compression per inch therefore equalled 11 tons at the period of failure. For a very short portion at (*c*) where the bracing ended, the angle irons of the lower cell, and that to which the lattice bars were connected, were not in one continued piece, and the whole weight passed through the side bars, which were, however, a little thicker here than elsewhere from a weld having been made at that point, so that the area of both side bars together equalled 6 inches. This short length was therefore subject to a compression of nearly 14 tons per inch. If we wish to compare the economy of this form of pillar with a tubular one, we must add the area of the lattice bars to that of the sides, in order to obtain the strain per sectional inch of

material in the whole pillar. The cross section of the internal lattice bars = 2 inches nearly; adding this to the area of the side bars and angle irons, we have the aggregate sectional area of the pillar = $9\frac{1}{2}$ inches, and the strain per inch of material employed 8·7 tons. This is a favourable result, when compared with those arrived at by Mr. Hodgkinson in his experiments on tubes subject to compression. We may regard the lattice pillar as one side of a tube, in the angles of which the chief part of the material is collected, and the sides of which are formed of bracing, connecting and holding the angle pillars in the line of thrust.

If, in place of being braced, the web connecting the side bars were made continuous like the side of a plate tube, and if for this purpose we reduce the thickness of the $\frac{5}{8}$ inch side bars so that the total amount of material remains the same, but leaving the angle irons as before, we shall have one side of a tubular pillar 26 inches wide, with the material contained in one side bar and the bracing (=4·5 inches) forming a plate ·17 inch thick, that is, a pillar the thickness of whose plating is 1-153rd of its breadth, and which is stiffened by angle iron at the corners. If the material in one angle iron be also distributed in the side of the tube the thickness of the resulting plate will be ·22 inch, that is, a tube the thickness of whose plating equals 1-118th of the width.

On examining the experiments instituted by Mr. Stephenson's directions, for the purpose of testing the strength of tubes subject to longitudinal compression, we find that the ultimate strength per inch depended upon the relation between the thickness of the plating and the width of the tube.

It is much to be regretted that the laws on which the ultimate strength depends, were not fully developed at the hands of such an able investigator as Mr. Hodgkinson, to whom we are chiefly indebted for a sound application of scientific principles to the investigation of practical questions

connected with the strength of materials. From his experiments on tubes I have made a rude deduction, that when the thickness of the plate is not less than 1-30th of the width of tube, and when there is no angle iron at the corners, then we may reckon on the ultimate strength being from 10 to 12 tons per inch.

In one experiment, made by Mr. Fairbairn, a tube 8 feet long, 18 inches square, with plates ½ inch thick united at the corners by angle iron, bore a pressure equal to 13·6 tons per inch. From this experiment and that made at Drogheda, I am inclined to make this inference, which I believe, if verified by further experience, to be one of much importance, viz., *The strongest form of rectangular cell to resist compression as a pillar, is one in which the chief part of the material is collected at the angles, leaving only so much material in the sides as is requisite to hold the angle pillars in the direction of the thrust.* With this also agree some theoretical investigations which I have made respecting the strains in the bracing of latticed pillars. If this principle, which I have enunciated, be true, then it ought to modify to a considerable extent the present practice of constructing the compression flanges of large beams either as one great tube or a series of cells. A tubular bridge, whether formed with plated or open-work sides, is a large tube whose top is subject to compression, and applying the principle just evolved, it follows that the best arrangement for the compression flanges is that in which they are formed of piles of plates riveted into a solid mass, and held in the line of thrust by their connexion with the sides and cross bracing.

The drawings, copies of which illustrate this paper, were made immediately after the experiment by Mr. William M'Carten, under Mr. Barton's direction, to whose courtesy I am indebted for their use.

The following experiments were made to try the effect

of slow and quick trains, with respect to vibration and deflection.

April 5th, 1855.—The lateral vibration at the centre of the centre span, from an engine and tender going at the rate of from 30 to 50 miles = ·05 inch on each side, *i. e.* the total oscillation equalled ·1 inch. Lateral vibration from a slow engine was scarcely perceptible.

Deflection at centre of centre span, measured on same side as the line on which engine and tender travelled, both for quick and slow speeds = ·25″. The same deflection was produced when the engine was brought to a stand at the centre of centre span. If any difference of deflection with different speeds was perceptible, those deflections produced by rapid travelling exceeded by a very small amount, perhaps the width of a fine pencil stroke, but for all practical purposes they were identical. On starting the engine from rest on centre of bridge, the deflection was momentarily increased to a very slight extent. There were about five quick trains, of which one travelled about 48 and the others 50 miles an hour, and about as many slow ones.

[14th December, 1858.]

M. B. MULLINS, Esq., President, in the Chair.

On Beams *and* Girder Bridges (Part 3).—By William Anderson, Esq., Associate.

In the papers I have already had the honour of reading before the Institution of Civil Engineers of Ireland, I endeavoured to show the direction and magnitude of the forces acting in the sides and flanges of uniformly loaded beams. I now propose to investigate the effect of unequally distributed or passing loads, and so close the theoretical treatment of my subject.

A passing load may chiefly be of two kinds: 1st, more or less concentrated in one point, like the carriage of a travelling crane; and 2nd, it may move on to the beam, and cover it completely before it begins to leave it again, as in the case of a train running over a bridge shorter than itself. In following these investigations, I propose again to make use of diagonally braced beams, as bases of argument, showing how results so obtained will coincide with those deduced from the method of moments.

In speaking of the girders made for the Dublin Exhibition, in papers which have since been published, I showed how certain diagonal bars found inactive under a uniform or central load, became of great importance when the weight was moved towards either end of the beam; and I now take the general case of a girder, with a single system of diagonal bracing, whose depth is one-twelfth of its length, and will trace the effect of a concentrated load travelling from one end to the other.

The several sections of the flange, A D, D E, E C, &c., in the beam A H R B (fig. 14), are supposed perfectly rigid beams, capable of transmitting the weight moving along them to the several points of attachment of the diagonal braces, the pressure on each point being in inverse ratio of the distance of that weight from the two nearest points. As the load leaves A and approaches D the diagonals H D and D J will experience a gradually increasing tensive strain, and when the point D is reached, H D will have to transmit $\frac{5}{6}$ W to the pier A, and D J $\frac{1}{6}$ W to the pier B, for obvious reasons, the resolution through the flanges and remaining diagonals taking place in the manner already fully investigated. Until the load actually reaches the point D, some portion of it is carried by the adjacent pier without the intervention of the braces; when D is passed its pressure on that pier diminishes, and the braces have therefore less to transmit in that direction, conse-

quently A H and H D are strained to the greatest extent when W is at the point D. The maximum strain in the flanges will also be in the immediate neighbourhood of this point while the load rests there, because a compressive force proportioned to $\frac{5}{6}$ W will be the resultant acting in H J, arising from a resolution of the tensive strain in H D, and the compressive one in H A. This will be met by a similar force, proportioned to $\frac{1}{6}$ W, acting along the flange towards H at each of the five points, J, K, M, P, R, making an aggregate pressure equal to $\frac{5}{6}$ W in H J, which is consequently the portion of the flange under greatest strain.

Similarly the bottom chord at D E will be strained by the resolution of $\frac{4}{6}$ W between H D and D E to the extent of $\frac{4}{6}$ W, increased further by the tension produced in A D by the resolution of the thrust of H A, and the vertical reaction of the pier, equal to $\frac{5}{6}$ W, making the entire tension $\frac{9}{6}$ W.

At each of the points E, C, F, G, the thrust of the struts resting there produces tensive strains amounting to $\frac{1}{3}$ W in each section of the flange, while the reaction of the pier B produces in G B a further tension of $\frac{1}{6}$ W. The collective effect of these forces acting from D to E will therefore be $\frac{9}{6}$ W, the exact balance of the pull from E to A, so that in D E the largest amount of tension will be.

In tracing the further progress of W, it will be found that the strains in D J and J E diminish, disappear to appear again reversed. The point X at which these bars are inactive can easily be determined, and the investigation is interesting and instructive, though not very important. Wherever X may be, the pressure of the load resting there, on piers A and B, will be inversely as A X and B X; therefore, if no forces are to pass along D J and J E, the entire load must be carried by the tension bars H D and E K, which can only take place when X divides D E in the same ratio as it cuts A B. Calling the entire length of the beam 6, we have—

$$\frac{1+Dx}{6} = \frac{Dx}{1}$$

$$\therefore Dx = \tfrac{1}{5}.$$

And the corresponding point in E C

$$\frac{2+Ex'}{6} = \frac{Ex'}{1}$$

$$\therefore Ex' = \tfrac{2}{5}.$$

When W reaches Y, the centre of D E, a very instructive arrangement of forces takes place. The pier A has to carry $\frac{3}{4}$ W, the pier B only $\frac{1}{4}$ W, but the two points D and E have to transmit $\frac{W}{2}$ consequently $\frac{1}{4}$ W has to travel back again from E along E J and J D, &c., to the abutment A. E J will have a tensive strain proportioned to $\frac{W}{4}$ J D compressive to the same amount, at D $\frac{W}{2}$ will be added, and H D will transmit in this way the required force proportioned to $\frac{3}{4}$ W.

In this manner the strains in flanges and braces may be determined for every successive position of the load, and a diagram, as fig. 15, constructed to show the variation of these strains, as well as their maximum value. The beam represented has only a single system of bracing, at an angle of 45°, and to avoid fractions in calculating the strains in the diagonals, the load has been taken as 50·9, being $\frac{72}{\sqrt{2}}$ moving along the bottom flange. The figures and formulæ along the bars indicate the greatest strains that can pass through them, those of compression being marked by the sign +, those in tension by —. Those bars that have two figures, with opposite signs, may be either in compression or extension, according to the position of the load.

It has already been shown that the maximum strain passed through a brace when the load was at its junction with the

flange, in which position the innate stiffness of the flange could yield very little support by spreading a portion of the load over other bars, consequently the introduction of a second system of bracing, as in figure 17, would afford no relief to the first without vertical connexion between the points of attachment of the braces, an important inference to which I will again recur when speaking of the construction of girders.

The coloured bands on the top and under the bottom of the beams, in diagram 15, are intended to show the manner in which the strains increase in the flanges as the load moves along. The blue band is the result of the load resting at the first intersection of the braces with the flange; the yellow indicates the additional strain elicited by the weight moving to the second intersection; the neutral tint shade marks the additional increase due to the load having reached the centre of the beam, while the red margin would define the strains arising from a load, double that which we have traced, moving along the beam, distributed evenly over it; and it is important to observe, that it includes all the other lines of strain; it is, therefore, the severest under which the beam can labour. It is especially remarkable in the top flange, that at each position of the concentrated load the greatest strain just reaches the curve for a uniform load, exactly corroborating the results obtained by the method of moments. On a former occasion it was shown that if a concentrated load $\frac{W}{2}$ cut a beam into sections S, S′ that the strain in the flanges at that point would be $\frac{W S S'}{2 l d}$ and that this equation would also correctly define the strain in every point of the flanges of a beam uniformly loaded with a burden equal to W. It follows from this that a girder, correctly constructed, to carry a uniformly distributed load, will also be fit to carry half that load concentrated at any one point, as far as its flanges are concerned.

If, instead of considering the concentrated passing weight equal to one-half the uniform load a girder is constructed to carry, we conceive it to be that portion of it resting directly on any of the sections formed by the intersections of the bracing of the beam with its flanges, (fig. 16) and trace its effect in transit from end to end in the manner already shown, a table may be formed, which, exhibiting the action of each fraction of the load separately, will give facilities for ascertaining the combined effect of any number of points loaded.

With a view to making this as clear as possible, I have constructed a diagram which is, in fact, a combination of the table above alluded to, and an illustrative drawing.

The diagram (fig. 16) represents a beam divided into 12 equal parts with a double system of braces, and their points of intersection with the flanges are numbered consecutively from the left hand corner. Eleven parallel lines are similarly numbered and drawn from end to end in the upper half of the beam. To avoid fractions, I have supposed the weight on each section to equal 12, diminished in the ratio of the depth of the beam to the length of the diagonal, and commencing with No. 1. I record in line No. 1 the effect of 12 on each bar in the system. The effect of the weight on apex No. 2 is similarly recorded in line No. 2, and so on through the whole beam, taking care to mark all tensive strains with negative signs on the left sides of the bars, while compressive strains stand with positive signs on the right side.

In the lower half of the beam are drawn similar horizontal lines in which are collected from above the strains resulting where 3, 6, 9 and 11 points are consecutively loaded, with an additional line in which are recorded the strains produced by the weight of the beam itself taken at one-third the passing load.

Let us suppose that the load has passed on as far as half-way between the points 6 and 7, consequently 1, 2, 3, 4, 5,

and 6 are fully loaded, and each portion of the load is producing its full effect in its own system of bracing as already recorded, so that to find the entire strain on any diagonal, we have only to add the figures appearing along it in lines 1, 2, 3, 4, 5 and 6. The diagonal, brace 0-1, for example, has a tension of 10 due to the load on point 2 acting on it, a tension of 8 due to load on 4, and a tension of 6 due to the load on 6; altogether, therefore, it is under a tensive strain $= -24$.

Again, brace $5-4$ shows a tensive strain of -1 and -3 due to the load resting on points 1 and 3, and a compressive strain of 7 due to the load on point 5; therefore $-1-3+7$ leaves a compressive strain of $+3$ passing through the brace. With the assistance of this diagram it is also very easy to determine at once what will be the maximum tensive and compressive strain in any brace, and in what position of load it will be found. Thus in $5-4$ we see that -4 is the greatest possible tensive strain, and as the figures -1 and -2 stand in lines 1 and 3, we conclude that this strain will be produced when the load has reached to half way between 3 and 4. The greatest compressive strain is $+16$, and is experienced when points 5, 7, 9, and 11 are loaded, because the figures making up 16 stand in lines 5, 7, 9, and 11.

In comparing the strains when the beam is $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, and fully loaded, it may be seen at once that many of the bars have to transmit both tensive and compressive forces, according to the position of the load—a circumstance very commonly lost sight of, though thus easily determined.

Having ascertained the strains in the diagonal bracing for four positions of the load, the corresponding effects in the flanges may speedily be arrived at by the method already described; and I have arranged a diagram (fig. 17,) to show this as clearly as possible.

The strains in the top flange are defined by ordinates to

curves; those in the lower, more correctly, though not so plainly, by ordinates to steps parallel to the beam. In both cases, it will be observed that the strains produced by a uniform load covering the entire beam, exceed those produced by any other position of it. The blue band indicates the amount of strain in the flanges when one-fourth of the beam is loaded; the yellow, neutral; and red tints show the increase of strain when the load has advanced over $\frac{1}{2}$, $\frac{3}{4}$, and the entire space successively; while the figures on the braces indicate the maximum force they will have to resist during the passage of the load.

I have hitherto considered a beam as destitute of weight, which, of course, is very far from being the case. Although no serious error would arise from this assumption in small spans, a very brief examination of the matter will show the rapidity with which the weight of beams increases with increase of their spans, and the great importance of considering it, both with regard to making sufficient allowance in calculating the strength of girders, and to the most economical proportion between the cost of the bridge and its piers.

If we examine the formula for the strain in the centre of the flanges $E = \frac{W\,l}{8\,d}$ we will find that it involves three variable quantities, the load W, the span l, and the depth of girder d. Now, W, the uniform load resting on the beam, may be represented as so much per foot, multiplied into the number of feet span:

$$W = w\,l$$

and, for purposes of comparison, the depth may be taken as a constant fraction of the length, say:

$$d = \frac{l}{12}$$

The formula then becomes:

$$E = \frac{3\,w\,l}{2}$$

from which it is plain that in beams constructed to carry the same load per foot, the sectional areas of the flanges vary as the spans.

Again, in plate beams, the strength of the sides depends on the shearing strain at the piers, where it is equal to half the load or $\frac{w\,l}{2}$, consequently the sectional area of these also varies directly as the span, and, generally, the cross sections of beams to carry the same load per foot, will vary as their spans. Now, as the quantity of material is found by multiplying the sectional area into the length, it follows that the weight of beams, as far only as their loads are concerned, will vary as the square of their spans, the loads increasing only as the spans; consequently the importance of the former will soon surpass that of the latter, till at last limits, comparatively narrow, are reached where the tenacity of the materials at our command becomes unequal to the support of their own weight.

For example: The Conway Tube is 400 feet span; 24 feet deep from centre to centre of cells in flanges, with an area of 645 square inches in the top flange; it weighs 1,112 tons. Allowing 4 tons to the square inch, as a safe compressive strain, the uniform load it is calculated to carry amounts to 1,238 tons, which leaves only 126 tons, or less than $\frac{1}{3}$ of a ton to the foot of running load in excess over what is required to support itself. In other words, the weight of the bridge is nearly 10 times that of the load it may safely carry, and is in fact the chief weight to be supported.

It is not my present purpose to enter minutely into the question of the ratio between the weights of bridges and their spans; enough has been said to show that the weight increases certainly quicker than the square of the span. It is, therefore, most important not to lose sight of this consideration in calculating even moderately large openings.

As far as the flanges are concerned, it is evident that the weight of a beam will merely act as so much additional uniform load, and may be involved at once with it in the equations for finding the strains in the flanges.

As regards the diagonal bracing, however, the proper proportion of the weight must be supposed to act at each intersection of the bracing with both the top and bottom flanges, as has been done in the lowest line of fig. 16, where the beam is supposed to weigh $\frac{1}{3}$ of the load. By adding the strains marked there to those indicated in any position of the load, it will be seen that the tendency of the weight of the beam is to keep the strains more of one kind throughout the bracing.

To show this more clearly, I have constructed the diagram, fig. 18. In the upper half, where the beam is supposed to be without weight, it will be seen that all but the last two braces may be either in tension or compression under a passing load. When the beam weighs only $\frac{1}{3}$ of the load, the last 8 braces are exempt from antagonistic forces; and when the weight of the beam increases to that of the load, only the four centre braces are liable to alternate tensive and compressive strains.

The practical results I hope to have obtained by the three papers now before the Institution is the establishment, by the simplest arithmetical and mechanical reasoning, of the following propositions:—

1.—There is no distinction in principle between what are known as "Plate," "Warren," "Lattice," or any other kind of girder, and it is probable that a wider application of the views here brought forward would tend to simplify many obscure investigations.

2.—If the flanges of a beam be constructed to carry a uniformly distributed load, they will also carry half the same load concentrated at any point of the beam, and either load passing over it.

3.—The main strain in the flanges of a beam is practically the same, whether it has plate or diagonally braced sides, provided these are properly proportioned; and the $\frac{1}{6}$ additional area, recommended by Mr. Fairbairn, for lattice beams, is unwarranted by theory or experiment.

4.—The strain in any point of the flanges of a uniformly loaded beam, is obtained by multiplying together the load and the sections of the beam on each side of the point selected and dividing by twice the product of the length into the depth. Corollary.—To obtain the strain in the centre, therefore, multiply the distributed load into the span and divide by eight times the depth.

5.—The sides of plate beams may be regarded as diagonal bracing, filling the entire space between the flanges, and their proportions may be calculated accordingly, though the size and number of stiffening pieces required to keep the plates in shape are, as far as I am aware, beyond the reach of calculation.

6.—The strains in diagonal beams of any kind may be made out with ease and accuracy, but no general formula can be given, because the nature of the load and the arrangement of the braces on which it depends, may be varied infinitely.

7.—For uniform passing loads, however, it may generally be said that the strains are greatest at the ends, and least in the centre; that some of the bars may, during the transit of a load, be under compression and tension alternately

8.—That the weight of beam should not be neglected in in computing its strength.

In concluding the theoretical portion of these papers, I feel it my duty to state that I claim no originality for the facts I have laid before the Institution. It is true that I have worked most of them out unassisted, and have arranged the whole matter in my own way; yet it is a pleasure as well as a duty to contribute thus publicly my poor tribute of gratitude to my

predecessors in the field of analytical investigation, to Mr. Blood, of Queen's College, Galway, who was the first to show the possibility of determining the strains in the diagonal braces of beams, and constructed the beautiful model of which the one below me is a copy, to illustrate and prove the correctness of his views; to Bow, who was one of the earliest writers on the subject; to Mr. Barton, whose graceful viaduct over the Boyne, is a national work we may well be proud of; and Mr. Stoney, to whom I am most indebted, and who, I believe, has studied the subject with depth and minuteness, if equalled, certainly not surpassed by any one.

I have ventured also to express dissent from the views of a man infinitely my senior in years, in experience, in scientific information, and literary renown. I trust Mr. Fairbairn and the Members of this Institution, will believe that I have spoken only with an earnest wish to remove what I believe to be erroneous views, and to uphold truth. I trust they will not ascribe to me an immodest desire to put myself against a man whose professional experience extends over more than half a century, who enjoys the high honour of having indefatigably assisted with his purse, his time, and his talents, the progress of mechanical engineering in this kingdom; and from whom, as his pupil, I have enjoyed the benefit of personal instruction.

The thanks of the Institution are due to Professor Downing for his readiness in lending me the model, belonging to Trinity College, with the assistance of which I have demonstrated the correctness of my views.

[11th January, 1859.]

M. B. MULLINS, Esq., President, in the Chair.

On the Cause *of* Failure *of* Bridges *on* Mountain Rivers. By John William Kelly, Esq., Member.

It is quite a common occurrence to hear of bridges on mountain rivers being swept away by floods, and thoroughfares rendered dangerous or impassable in consequence; sometimes causing serious accidents, and at all times much public inconvenience. The great rain and floods that occurred in September last, have been productive of wide-spread damage in these respects. In the mountainous districts of Kerry, Mayo, &c., the casualties have been numerous and important: and apart from the many inconveniences arising from them, the large expenditure rendered necessary for repairing the damages is of no slight consequence, amounting as it must do to large sums of money.

If there be any principle or contrivance, by means of which these casualties may be prevented, or their number diminished, its discussion before this Institution would be desirable; in order that, if deemed practicable, it may obtain a larger degree of notice and confidence than it otherwise could be expected to receive. Believing that there is such a principle, and that its application is practicable and simple, induces me to submit this brief paper on the subject to your consideration.

The writer should perhaps feel no small degree of apprehension, that if the principle were such as he imagines it to be, its simplicity must long ere now have insured its more general application; but we are all aware of the curious fact, that many common occurrences of great interest pass before us, day after day, without investigation—our perfect familiarity with their effects rendering us quite unconscious of our

ignorance of the causes. In short, we do not think of raising questions, being satisfied we know all about them. This is particularly the case with occurrences that are familiar to us from early youth upwards; and amongst them may, perhaps, be classed mountain floods, and the casualties attending them. If we hear of the destruction of bridges on mountain rivers, it is merely the old story, and, of course, followed by the old reply, "Oh, the great floods swept them away." If required by any chance to assign reasons, we very off-handedly name, the insufficiency of size of arch, the badness of foundation, inferiority of masonry, or possibly the piers or abutments being badly placed with reference to the direction of the current. We rarely, perhaps, investigate the exact manner in which the floods act in producing the catastrophe.

No doubt, a bridge labouring under any one or more of the deficiencies mentioned, is very liable to give way under the force and action of a mountain flood; but it is submitted, that a bridge may be all right in these particulars, and yet that there is another requirement without which it is by no means secure.

What, then, is this additional requirement? It is that the channel or waterway, for some short distance above, through, and below the bridge, should be of equal discharging capacity; and more particularly that the channel below should on no account be of greater waterway or discharging capacity than the arch or arches of the bridge.

It is the great "head of water" above, and sudden fall hrough, or at the down-stream face of the bridge, that produces all the damage. Reduce the channel *below* to the discharging capacity of the bridge, and the character of the action of the descending waters is changed, the sudden falls disappear, and the object sought is attained. If the bridge afford sufficient waterway, there is no reason why the channel below it should be larger; if it do not afford sufficient water-

way, it becomes still more necessary, if the bridge is to be preserved, that the channel below it should be reduced to an equal capacity. If the bridge be of greater waterway than the channel *above* it, then the portion of the channel immediately *below*, should be brought to an equality of discharge with that *above* the bridge; either by increasing the capacity of the channel above, or reducing it below the bridge, as the necessities of the case and local circumstances shall render most expedient; bearing in mind that the channel below is on no occasion to be of greater discharging capacity than the bridge, and that the object sought to be attained, is to convey the floods in a comparatively moderate incline and velocity through, and for some distance below, the bridge. This can be done, it is submitted, by regulating the discharging capacity of the channel as above suggested.

It is quite a common occurrence to find a deep hole scoured away just at the down-stream face of a bridge. This is caused by the great action of the water as it issues from the arch—which not unfrequently may be seen pouring forth as if issuing from a sluice. Of course the extension of the holes up under the arches, is a mere matter of time, more or less remote, according to the tenacity of the foundation, and the frequency and scouring power of the floods. In order to save the bridges in such cases, the practice is often resorted to of filling the holes with stones, &c., but the destructive cause remaining, a few subsequent floods, if not the very first, scoop out the holes again, and the destructive action proceeds as before. But even where no such holes can be formed—the bridges being built on the solid rock—they have often yielded under the force of a large head of water—generally to the action of the flood upon the (too often inferior) masonry of the piers and abutments. The remedy in all these cases, as above stated, is to contract the channel below the bridge, so as to overcome the falls, and instead of allowing the floods to roll down in

destructive rapids through the bridge, to raise them into comparatively deep volumes, moving with an easy incline and velocity.

The manner in which the contraction of the channel may be effected will vary with local circumstances. In general, rough hammer-dressed side walls will be found to be best and most convenient; they should be brought to the required width apart, at, or a little below the Bridge, and, after running parallel for ten or fifteen yards down stream, to commence to *open out gradually* to the general width of the channel. Where stones cannot be conveniently procured, the simple contrivance of projecting jetties, formed of rough piles and wicker-work, will be found useful.

The writer had an opportunity of seeing the principle here advanced tested on two occasions. The first was in the case of a new arch, 25 feet span, over a mountain river, and erected on a very compact limestone gravel foundation. At the down stream face of the bridge the channel was wider than it, by about three feet at bottom, and, owing to the side slopes, it was about 18 feet wider at flood level than the arch. There was a Weir about 60 yards below the Bridge, and the channel opened out gradually still wider down to the weir basin. The result was that the floods, which at best were rapid enough, attained a sudden fall on issuing through the arch into the comparatively wide channel below; and a corresponding scouring power was brought to bear on the centre of the channel, just at the down stream face of the Bridge. A hole was in course of quick formation, but detected ere it was scooped more than a foot in depth. The channel was immediately reduced to the width of the arch by means of rough hammer-dressed side walls, which, after some ten yards below the Bridge, were made to open out *gradually* towards the weir basin. The expectations formed were perfectly realised. The floods subsequently came through the arch, and

for some distance down stream, in a comparatively easy incline, producing no further harm; and had the former state of things been suffered to continue, it is probable that in a very few years the Bridge would have been reduced to a most precarious position.

The second instance was a small accommodation bridge, some 12 feet span, not more than eight feet in width between the parapets, and composed of rubble masonry. It was built over the *old* course of a mountain river, and was intended only for passing the waters of a small tributary—over nine-tenths of the waters of the catchment basin being intended to be sent down in a *new* channel. Just after the completion of the small rubble bridge, and ere the new channel was ready for opening, a flood occurred, which had to be sent round by the old course. The bridge, though fully equal to the purposes it was intended to serve, was altogether insufficient in waterway for discharging the mountain floods of the whole catchment basin, and the waters rose in consequence nearly two feet over the soffit of the up stream side. Fortunately the channel some 20 yards *below* the bridge, although deepened, was much contracted in width (not, it must be confessed, through design, or in anticipation of an event of this sort, but merely to dispose of the spoil), and the waterway was only about equal to that of the bridge. The result was, there was very little head water, the difference of level between the flood waters above and below the bridge being only a few inches; and the fresh rubble structure which, under other circumstances, would be endangered, was quite safe.

It is, perhaps, unnecessary to pursue this simple subject any further. If the principle treated of be sound, it needs no further illustration. The questions to which attention is solicited, are—Whether even a sufficiency of waterway and good masonry, in bridges over mountain rivers, are sufficient to ensure their stability, unless the flood waters are conveyed

in a comparatively tranquil manner through the arches? And whether the adjustment of the channel adjoining the bridge, as above described, is not the most simple and effectual, if not the only way of effecting this object? Also, whether the application of the same means is not calculated, in many cases, to save bridges labouring under defective masonry and waterway?

It is not, of course, intended to advocate defects of any kind in bridge building; but it may often be desirable to maintain even a defective bridge, to avoid public inconvenience, or the expense of building a new one.

In connexion with this subject, it may not be out of place to draw attention to a remark very often made, namely, that the proper provision for waterway in Bridges is generally disregarded, or forms but a very secondary consideration with Road makers. That it has been so heretofore must, perhaps, be admitted to be the fact. In prosecuting the Arterial Drainage of Ireland, which lay generally in the lower parts of the country, it is well known that most of the bridges encountered were so defective in waterway, and in other respects, as to involve the necessity of having them taken down and rebuilt; and the numerous casualties we hear of from time to time would lead to the inference, that a want of due attention to similar requisites must prevail to some extent in the higher parts also. It is, perhaps, needless to observe that this state of things is not attributable to the present County Surveyors, than whom, it is well known, it would be difficult to find a more intelligent body of men in any profession, and under whose surveillance we are justified in expecting that due attention will be paid to the double purpose a bridge should serve—that whilst making provision for the roadway, the no less essential desideratum of making ample provision for the waterway shall not be neglected. This latter desideratum involving, as it ought, the consideration of the extent

and physical character of the catchment basin of each river and stream, is not so simple as may have been too often imagined; on the contrary, it is calculated to exercise one's reflection and ingenuity; and, at all events, it is both necessary and important that it should not be disregarded. Curtailing the legitimate cost of a roadway, by making bridges of inadequate waterway, and inferior masonry, is questionable economy; and the old adage, that "whatever is worth doing at all is worth doing well," is, perhaps, in no other case more worthy of application than in Bridge building.

The recent failures of so many bridges on mountain rivers renders, perhaps, the present time opportune for raising the question as to the cause of those failures; and it is with this view, and not through any impression of being able to invest the subject with any particular interest, that the writer is induced to submit this brief paper to your notice.

ENNIS, 10*th December*, 1858.

[8th February, 1859.]

M. B. MULLINS, Esq., President, in the Chair.

DESCRIPTION *of a* HIGH WEIR *built across a* MOUNTAIN RIVER.—By JOHN WILLIAM KELLY, Esq., Member.

AMONGST the numerous subjects brought under the consideration of the Institution from time to time, there are, perhaps, few deserving of notice more than failures in works of interest and magnitude—the causes that led to such failures, and the means resorted to for overcoming them. The subject of this paper is an account of the failure of a high weir built across a mountain river, and a description of the weir by which it has been replaced.

The Cloon weir—the one alluded to—forms part of the

works of the Annagh Drainage District, and a brief description of that district may render the subject under consideration more intelligible.

The Annagh district is situate in the county of Galway, close to the road from Gort to Loughrea, and about two miles from Gort. It lies at the foot of the western slope of the Sleive Baughta mountains, just where the limestone terminates against the sandstone, of which latter the mountains are composed. The Annagh river issues from these mountains, and is exceedingly rapid, until it enters the drainage district, where it becomes comparatively level. The flat plain constituting the drainage district, is separated from the lower country by a ridge or "Esker," composed, as usual, of limestone gravel and boulders; and the river, which generally maintained the centre of the catchment basin, was intercepted by this esker, sent round in a circuitous course, and, forcing its way through a low part of the esker, doubled back again at the lower side of it, and thence descended in a series of rapids to Ballylee turlough; there to disappear in subterranean passages. This lower part of the country presents many of the curious phenomena peculiar to the cavernous limestone formation; but any further notice of it here, or of the physical circumstances of the Annagh river and its mountain catchment basin, is perhaps unnecessary. On reference to the accompanying diagram map, Drawing No. 1, some further information on the subject may be obtained, if required.

Those who have had to deal with mountain rivers, know they are not altogether as manageable as might be deemed desirable. The most effectual, if not the only way, of properly controlling them, is by means of reservoirs, for the retention and subsequent gradual discharge of the mountain floods. The district to be drained in this case, and the mill power at Cloon to be maintained, were not of sufficient importance to warrant the construction of reservoirs; and the next best course to

adopt, was to make provision for letting the floods run off, at a sufficiently low level, as fast as they came down. A new channel through the esker was the most suitable for this purpose; and where the cutting became light on the lower declivity of the esker, a weir was made across the channel for affording a water supply to Cloon mill, and for other purposes.

The excavation through the esker for the new channel, including that for the weir, reached a depth of 33 feet; a crowbar was driven down about 4 feet more, and nothing was met with all through but limestone gravel, and boulders; the hope of reaching the rock *in situ*, at any reasonable depth, was thenceforth relinquished, and the design for a weir, represented on Drawing No. 2, was adopted. It consisted of a straight weir or overfall, 60 feet in length, and 16½ feet in height. It was built in steps, as shown in section, so as to break the descent of the waters into three falls, of about 5½ feet each; the thickness of the masonry at the base was about 10½ feet, and at top 5 feet; the batter of the face work between the steps was 1½ inch to a foot, the projection of each step 2 feet; the top coping, and the coping of the steps, were composed of large weighty stones, and the face work of good ashlars (roughly faced, but of good beds and joints); the coping of each of the steps was let in about 18 inches under the course next above it; the toe of the weir was closely paved in front with heavy blocks of stones, and for some distance behind the top of the weir it was also paved to preserve the puddle backing.

Over the weir thus briefly described, the river passed for several months, and the succession of regular water-falls presented as picturesque an object of the kind as need be desired. Some of the larger floods, in going over it, went clear beyond the first step (from top), descended upon the second step with great force, and thence fell harmlessly to the

bottom. The swell of the flood having passed, the waters resumed the fall from step to step again as usual. The *extraordinary floods*, however, contrary to expectation, overshot the whole weir, and descended with unchecked force and volume on the pavement below, the large blocks of stones composing which were torn up and tossed about in the watery tumult, almost like so many logs of timber.

The flood waters having subsided, a dam was thrown across the new channel, and the river sent round in its old course again. Upon examination it was found that, with the exception of portions of some of the bottom courses that fell out, after the foundation was worn from under them, the weir was apparently little injured; but the flood waters not only tore up the paving for about 10 feet in breadth all along the foot of the weir, but also excavated clean down to the solid rock, which was only 5 or 6 feet under the lowest course of masonry. Had it been known ere the weir was built, that the solid rock was so near at hand, the design and circumstances attending it, in all probability, would have been different.

As the structure suffered apparently so little, rather than take it down for reconstruction, it was deemed advisable to underset with masonry itself and wing walls, down to the rock. This was accordingly done; but when the river was turned over the weir again, the joints in the masonry were found to be by no means staunch, as before. This arose, it is considered, from a slight settlement of the weir, occasioned by the tearing away of the foundation at foot of it, and also by an opening that ensued between the puddle backing and the masonry. It withstood, however, the action of several floods afterwards; but in the month of August, 1849, a series of heavy floods occurred in succession, and came down so impetuously, that they carried with them, from the sides of the new cut, several large boulders (some of them over half a ton weight) and rolled them over the top of the weir. In falling, the boulders

broke some of the coping stones of the steps, and dislodged others, thus leaving some of the interior masonry exposed to the action of the water. The leakages increased, and the work of destruction progressed, slowly, indeed, but continuously; and finally, the waters having found space down behind the weir (the puddle backing having been partly carried away), produced such a hydraulic pressure forward, as to occasion a bulge, which subsequently yielded in a breach.

The breach was in the middle of the weir, and of about 25 feet in length by 15 feet in depth, leaving the ends, the wing walls, and the whole of the *undersetting*, all the way across, undisturbed.

It was now determined that the weir should be altogether reconstructed; and a strong dam was therefore made across the new channel, and the river once more sent round in its old course, until the present weir should be built.

If it were desirable or necessary, much might be adduced in extenuation of the failure of the first weir—the great hurry under which the Surveys of Drainage Districts were made, and the works entered upon, under the "Summary Proceedings Act," for the purpose of giving employment to the famishing poor in 1847, and so forth; but it must be admitted that insufficient knowledge of the quantity of water poured down by mountain rivers, during extraordinary floods, was the principal cause. At that time (1847) our knowledge of river discharges, and particularly of mountain rivers, was not very precise nor extensive; nor perhaps does it prevail even yet to as great an extent as would be desirable. The greatest flood in the Shannon, within the last twenty years, occurred in January, 1853, when the discharge at Killaloe reached the enormous quantity of 1,617,110 cubic feet per minute; yet this great discharge of the "mighty Shannon" amounted only to 0·699, or less than three-fourths of a cubic foot of water for each acre of catchment basin. Few of the Irish

rivers on which observations have been made contribute more than from one to two cubic feet per acre. The large floods in the Annagh river, however, yield no less than from 8 to 10 cubic feet per minute for each acre of catchment basin; and a summer flood that occurred on the 12*th of June*, 1851, attained the enormous discharge of 13·02 *cubic feet* per minute for each acre! being 18 *times* greater than the maximum acreable discharge of the Shannon.

Had the acreable discharge been not more than four or five times that of the Shannon, it is probable the weir would be still standing; but the actual discharge so far exceeded the expectations formed, as to render the provision made for breaking the fall, and the easy descent of the waters, altogether inadequate.

It will easily be imagined how much the failure of the first weir was calculated to stimulate every precaution in preparing a design for the second, as well as attention to its construction, so as to prevent the recurrence of any further casualty.

The present weir, as designed and built, is represented on Drawing No. 3. On plan it is an arc of a circle, the chord of which is 60 feet, versed sine 15 feet, and length of arc at apex of weir nearly 70 feet. The height of the weir is 19 feet 8 inches; thickness at bottom, 10½ feet; and at top, 5 feet. Each end of it terminates against a heavy abutment of masonry, and altogether it may be considered a stone arch, laid on its side, presenting its back to the force of the current.

The foundation was prepared on the solid rock, and the first course sunk or embedded into it, leaving a solid check in front, of about four inches in height, all round the toe of the weir and lower wing walls. It is built in courses, laid at right angles to the batter, which is 1½ inch to a foot; each course is divided into a number of voussoirs, as it were, by extending the radiating joints from the front through the packing or rubble masonry to the rere, as shown in Fig. 3, Drawing No.

3. This is one of the peculiarities of construction to which attention is invited. The front work is composed of heavy rustic ashlars, with bonds of from 4½ to 6½ feet in length, at intervals of about 8 feet apart; and the back, also, is composed of somewhat similar but lighter ashlars, with tail bonds at similar distances apart. The packing or rubble work, between the front and rere ashlars, contains a large number of flags, obtained from an adjacent crag, and they also aid in bonding the whole together. Care was taken to make the stones in each successive course break joint with those immediately under, to intersperse the bonds properly, and to pack and make the rubble work as close as possible.

All round the back of the weir and abutments a puddle bank is raised, over which is a layer of concrete, and over that again, and extending a little beyond it, a stone paving, 18 inches deep.—(See Fig. 2, Drawing No. 3.)

The puddle bank was composed of three parts of tenacious blue clay, and two parts of compact limestone gravel, well mixed and tempered, and laid in 18-inch layers. This formed excellent puddling material, and its staunching effect was increased by the successive layers overlapping the small steps in the back courses of the masonry—(see section)—thus effectually preventing the possibility of the water getting down between the puddle backing and the weir. The upper wing walls were also carefully puddled behind, up to the top level, which is 5 feet 6 inches over the apex of the weir.

The concrete was composed of three parts of broken limestone, two parts of clean river sand, and one part of powdered unslacked fresh burnt roche lime.

The paving was composed of stones roughly scabbled, laid close and wedged, and afterwards grouted flush to the surface.

It is to be regretted that, in consequence of the sum for executing the works being limited under the provisions of the "Summary Proceeding Acts," the wing walls and retaining

walls, above and below the weir, could not be built for a greater distance on either side of as good materials as would be desirable. This is the more to be regretted, as the Trustees appointed under the Drainage Acts for conserving the works of the District, have left inoperative the powers vested in them; and the works, although requiring repairs, have been left to their fate. The weir itself, however, and its immediate adjuncts, are as well and substantially built as need be.

Such is the Cloon Weir, as at present constructed, and any further details that may be required will, it is hoped, be found in the Drawings. It is now built about nine years, and during that time it has been as severely tested as it probably ever can again. Indeed, it is difficult to imagine any force calculated to injure it, unless such as would displace simultaneously the whole mass, and under none of the contingent circumstances, of even a mountain torrent, can this be considered probable. During a large portion of the summer season the weir is quite dry, the whole of the river water being drawn off in working the small mill close by; but in the winter season, and particularly during the maximum stage of the floods, the picture presented by the deep impetuous fall of such a great volume of water is really formidable, and well calculated to convey a vivid idea of the immense power of falling water.

It has been frequently observed, that amongst the younger members of our profession—and the observation might be extended, perhaps, to the old and young members of all professions—that a large degree of reluctance prevails against giving publicity to any failures in which they may have been personally engaged. It may not, indeed, be the most agreeable task a person could impose on himself to describe a personal failure, yet, unless in very rare cases, there is no sufficient reason why he should not. It is well known that there are few, if any, persons of much practice in any profession who have not met with failures, and from those failures drawn

their most valuable experience. And there can be but little doubt that, if the sources from which those failures arose, and the manner in which they may have been overcome, were more generally imparted, it would conduce much to the prevention of similar ones. Let us, then, hope that this is but the forerunner of many similar, but more interesting, accounts of failures, and difficulties overcome, that shall be submitted to the Institution.

ENNIS, 27*th December*, 1858.

[8th March, 1859.]

M. B. MULLINS, Esq., President, in the Chair.

OBSERVATIONS *on the* NEWCASTLE COAL EXPERIMENTS.—By BINDON B. STONEY, Esq., Member.

IT is, doubtless, still fresh in the recollection of the members of this Institution, that in the year 1855, the Steam-coal Colleries Association, of Newcastle, offered a premium of £500 for the invention of an effectual method for preventing the emission of smoke from the chimneys of multitubular boilers. The terms of the competition were as follows:—

"No design shall be deemed entitled to the premium unless it be in conformity with the following conditions:—

(*a*) "It shall effectually prevent the production of smoke during the combustion of any of the Hartley steam coals of the North of England.

(*b*) "Such prevention shall be accomplished by the combustion of the smoke or gases in the furnace or air chamber previous to passing through the flues or tubes.

(*c*) "It shall be applicable to all the usual forms of boiler, containing a number of small tubes between the furnace and the chimney, and especially to the usual forms of marine boilers.

(*d*) "It shall not diminish the evaporative power of the boiler to which it may be applied.

(*e*) "It shall not impair the durability of the boiler.

(*f*) "It shall, as far as possible, be independent of the personal attention of the stoker or engineer, but it is not essential that it should be absolutely so.

(*g*) "It shall not be, or be made, the subject of a patent, or, if so, the inventor or patentee shall undertake that the patent right shall not exceed in amount such rate per horse power or per foot of fire grate as the judges may determine."

Induced by this prize, 103 competitors presented designs, of which four, including that of the author, were selected for further trial by the judges. The method which the author proposed is best explained by the following extracts from the description of his plan, which he submitted to the judges in August, 1855:—

"Description.—The fire being supposed fully lighted, and a mass of glowing coals spread over the bars, fresh fuel is placed in considerable quantity on the shelf, and the fuel so placed is, in front, subject to the full heat of the fire, which cokes the coal for a considerable depth into its mass, causing it to yield its inflammable gases *uniformly* and *prolonged* over the full period of each charge.

"These gases, passing through and over the ignited fuel, are intensely heated, and meeting with several jets of air, admitted through the valve of the double door and the perforations in the inner plate, ignite as they pass over the glowing coal on the bars. The flame thus produced has a run equal to the *whole length* of the furnace before reaching the tubes, which is a matter of extreme importance in multitubular boilers, where the usual effect of the tubes is to extinguish the gases, which are only just ignited, close to their mouth, and which therefore have not had time or space sufficient to ensure their combustion before reaching the tubes. In the proposed method the flame has the longest possible run, viz., the whole length of the furnace, and this prevents waste of half-burned gases passing up the chimney, or, what is still more serious, the risk of taking fire again in the uptake.

"When the fire on the bars requires renewal, the coked mass near the mouth is shoved forward, and, from the inclination of the fire-bars, is easily spread over their surface.

"The door moves vertically in slides, so as to be opened to a greater or less extent, according to the quantity of fuel supplied.

"One great collateral advantage of this method is the perfect coolness at the stoke-hole; for since coal is a non-conductor of heat, none is transmitted from the furnace outwards, through the outer portion of fresh coal.

"In this design the supply of inflammable gases being uniform, and the supply of air being constant, the heat developed by the furnace is nearly quite uniform, thus insuring in the boiler an uniformity of evaporation, which in the ordinary method of throwing cold fuel on the glowing fire is quite impossible to attain.

"The merits of the above design may be summed up as follows:—

"1. A *gradual* and *prolonged* development of inflammable gases.

"2. A supply of air *sufficient* for, and *proportioned* to, the production of gases, which can be regulated at will, and which is quite distinct from air supplied to coked fuel on bars.

"3. The mixture of gases and air passing over glowing fuel cannot avoid combustion.

"4. Great uniformity in the evaporative power of the boiler, which is never suddenly cooled down, from the placing of fresh fuel over that already incandescent on the bars.

"5. Durability of boiler in consequence of uniform supply of heat.

"6. Flame has the *longest possible* run for its action, viz., the whole length of the furnace, and therefore the gases have time to be consumed by the time they reach the tubes.

"7. The smallest slack can be burned with as much facility as the best coal, since it is in coked lumps when it reaches the bars.

"8. The firebars may be placed wide apart, for the same reason.

"9. Perfect coolness at stoke-hole, which, especially in marine engines, is a matter of importance.

"10. Cheapness of application, requiring no complicated machinery, and in every respect as durable as the ordinary furnace.

"11. Applicability to all boilers.

"*July 27th*, 1855."

After a lapse of more than two years and a quarter, the author received the following letter from the Secretary of the Association:—

"58, WESTGATE-STREET, NEWCASTLE,
"*Nov.* 18*th*, 1857.

"DEAR SIR,—I beg to give you notice, the judges appointed by the Steam-coal Association have selected your plan of preventing smoke for trial, and herewith I send you a tracing of the boiler, which will give you an idea of what is required. Hoping to hear from you,

"Yours, &c.,
"WM. REED.

"B. B. Stoney, Esq."

The experimental boiler was, it will be perceived, a multitubular boiler of the marine type.

Three days after receipt of this letter the author forwarded to Mr. Reed the following reply, together with a tracing of the plan of firebox which he considered suitable for testing his method. (See plate.)

"DUBLIN, *Nov.* 24*th*, 1857.

"DEAR SIR,—In reply to your letter of the 18th instant, I beg to enclose a tracing of a simple arrangement by which the experimental boiler may be adapted, at little expense, to my method for smoke prevention.

"The fire-bars should be placed slightly wider asunder than is usual with the description of coal experimented upon, and the fuel on the bars may be a little deeper than is usual. This is owing to the partial coking which takes place in the coal before it reaches the bars.

"The door box is so designed that a thin film of air (say quarter of an inch wide) enters between the door and lower edge of arch.

"If too much air gain access, which is unlikely, some of the holes may be temporarily plugged. If too little, the door must be left open a slight amount. A few trials will determine this. When the furnace is in full action the coal should, at each charge, be heaped up as shown. When the fuel on the bars requires renewal, the upper and front part of heap are to be shoved forward and spread over bars. This being the coked or partially coked portion of heap will not have the tendency to produce the smoke that fresh fuel on the bars would have. The hinder portion of heap is then to be shoved into the front of heap, and fresh coal supplied to bring heap up to original size.

"I remain, &c.,
"BINDON B. STONEY.

"William Reed, Esq."

On the 19th December the author received the following letter from Mr. Longridge, one of the three judges:—

"58, WESTGATE-STREET, 19*th Dec.*, 1857.

"SIR,—I beg to inform you that your plan for smoke prevention will be ready for trial on Thursday next, and will be glad to hear if you intend being present personally, or sending any person on your behalf. An answer per return will oblige, yours, &c.,

"J. A. LONGRIDGE.

"B. Stoney, Esq."

To this letter, appointing the day before Christmas for trial, the author, who was from home in the South of Ireland, replied as follows:—

"BALLAST OFFICE, DUBLIN, *Dec.* 22*nd*, 1857.

"SIR,—In reply to yours of the 19th instant, I beg to say that I am unable to attend in person during the trial of my plan for smoke prevention on next Thursday. I do not think there is anything of consequence that I can add to my former description of the proposed arrangement.

"One or two slight modifications of the method of manipulation may suggest themselves at the first trial, but as I have not had an opportunity of trying my plan on the large scale of your experimental boiler, and as I am not familiar with the coal employed, I believe my personal presence is the less necessary; however, I regret this the less since I feel confident that whatever merits the proposed plan may possess will not be overlooked by the gentlemen who are appointed judges in the matter.

"I am, &c.,

"B. B. STONEY.

"J. Longridge, Esq."

The announcement of the final award appeared in the *Times* of January 27th, 1858, and after some days the author, on application, received a copy of the judges' reports, from the second of which the following extracts are taken*:—

"10. In the month of August, 1855, we met for the purpose of arranging our proceedings, and made a cursory examination of the plans which had

* See *Engineer*, vol. v., p. 99.

been sent in, rejecting those which were obviously either inapplicable or impracticable. To the authors of the others, we addressed a circular through your Secretary, stating that their plans were retained for further consideration.

"11. As soon as the boiler was ready, we proceeded to experiment upon it, in order to determine the standard of reference. Much time was occupied in these trials, and in the course of them we arrived at the striking results already communicated in our first report, viz., *that the evaporative power of the coal was much greater than had been previously stated, and that smoke could be prevented with ease, and at the same time with a decided advantage to the effective power of the boiler.*

"12. In all these and the subsequent experiments, the details were carefully registered, the whole of the coals weighed and water measured. The weights of ashes, cinders, and clinkers which were left were weighed. Diagrams of the temperature of the escaping gases obtained by a pyrometer, and a number of other particulars recorded, which would occupy too much space to enter upon in this report.

"13. Although we arrived at results exceeding in some respects those obtained by any of the competitors, we have not thought it fair to take our *best* results as the standards of reference, because, being the issue of a long series of carefully-conducted experiments, we felt that to take these results as standards would be going beyond the spirit, though not perhaps beyond the letter, of the published conditions.

"14. We have, therefore, established as the standard the means of a series of experiments during which the firing was conducted according to the ordinary system, every care, however, being taken to get the maximum of work out of the boiler by keeping the fire-grates clean and by frequent stoking. No air was admitted except through the fire-grates, and as a consequence much, and often a very dense smoke was evolved.

"15. As the economic effect of the fuel increases when the ratio of the fire-grate surface to the absorbing surface is diminished, we have adopted two sizes of fire-grates, and consequently two standards of reference. With the larger fire-grate, the amount of work done by the boiler per hour is the greatest, but this is done at a relative loss of economic value of the fuel as compared with the smaller grate.

"The one gives us the standard of maximum evaporative power of boiler, the other the standard of maximum economic effect of the fuel.

"The fire surfaces used for fixing those standards were 28½ square feet and 19¼ square feet respectively.

* * * * * * * *

"32. The standards of reference alluded to in the 14th and 15th paragraphs of the present report are as follows:—

—	Fire Grate 28½ square feet		Fire Grate 19¼ square feet	
	A	B	A	B
Economic value, or lbs. of water evaporated from 212° by 1 lb. of coal, ...	9·41	11·15	10·06	12·58
Rate of combustion, or lbs. of coal burned per hour per square foot of fire-grate, . . .	21·15	19·00	21·00	17·25
Rate of evaporation per square foot of fire-grate per hour in cubic feet of water from 60°, .	2·62	2·93	2·909	2·995
Total evaporation per hour in cubic feet of water from 60°, ...	74·80	79·12	56·01	57·78

"The columns A contain the standards of reference alluded to in paragraph 15, whilst the columns B give the *mean of the best* results obtained by our own experiments *when making no smoke.*

"33. The first plan submitted for trial, was that of Mr. Robson, of Shields, which we selected as a type of several of the plans comprised in Class 3, and as in our opinion the most likely of its kind to prove successful. The principle of this plan is to divide the furnace into two fire-grates, the one at the back being shorter than the other, and placed at a lower level. This back grate is furnished with a regular door-frame and door, for the purpose of enabling the stoker to clean the bars and remove the clinkers when required. This door is also provided with an aperture fitted with a throttle valve, and in the inside a distributing-box perforated with half-inch holes, after the manner practised by Mr. Wye Williams. The front grate is like the ordinary fire-grate, but without any bridge. The mode of proceeding is to throw all the fresh coal upon the front grate, and to keep the back or lower grate supplied with cinders, or partially coked coal, which is pushed on to it from time to time from the upper or front grate. No air is admitted at the door of the upper grate, but the gases arising from it meet with the current of fresh air admitted through the door of the lower grate, and in passing over the bright fire upon it are to a greater or less degree consumed.

* * * * * * * *

"42. The next plan submitted to trial was that of Messrs. Hobson and Hopkinson, of Huddersfield. In this system air is admitted both at the doors and at the bridge. At the doors by means of vertical slits, which may be opened or shut at will by a sliding shutter, and at the bridge

through apertures in hollow brick pillars placed immediately behind it. The entrance of the air to these pillars is regulated by throttle valves, worked by a lever in the ashpit. There are also masses of brick-work placed in the flame-chamber, with the intention partly of deflecting the currents of gases, so as to ensure their mixture with the air, and partly to equalise the temperature.

* * * * * * * *

"50. The next plan tried was that of Mr. C. Wye Williams, of Liverpool.

"Mr. Williams' system, as is well known, consists in the admission of air at the furnace door, or at the bridge, or at both, by numerous small apertures, with the intention of diffusing it in streams and jets amongst the gases. In the plan adopted in the present instance, Mr. Williams introduces the air only at the front of the furnace, by means of cast iron castings, furnished on the outside with apertures provided with shutters so as to vary the area at will, and perforated in the inside with a great number of half-inch holes. The mode of firing which Mr. Williams adopts merely consists in applying the fresh fuel alternately at opposite sides of the furnace, so as to leave one side bright whilst the other is black.

* * * * * * * *

"59. The next and last plan submitted to trial was that of Mr. B. Stoney, of Dublin.

"In principle, so far as regards the prevention of smoke by the admission of air through the doors, and at the front of the furnace, this plan is identical with that of Mr. Williams. Its peculiarity consists in the adoption of a shelf outside the boiler, forming, in fact, a continuation of the dead plate outwards. Upon this shelf the fresh charge of coals is laid in a large heap, about half of the heap being within the furnace, and the rest outside. The door is a sliding frame, which shuts down upon the top of this heap of coals, so that air is admitted through the body of the coals, as well as through perforations in the front plate of the furnace. When the furnace requires fresh fuel, a portion of that forming the heap, and which, to some extent, has parted with its gases, is pushed forward and its place made up by fresh fuel laid on in front.

"60. This plan did not succeed in preventing smoke, for whenever the coal was pushed forward upon the fire, dense smoke was evolved.

"We regret that Mr. Stoney was not personally present to see the result, which we think would have entirely satisfied him that the method he proposed did not comply with this important condition. Under these

circumstances, we did not proceed to determine the economic value of the fuel or work done by this system.

"*60a.* In the following tables the results in each case are compared with the standards, and also with those of our own experiments when making no smoke. The former marked A, and the latter B.

LARGE FIRE-GRATES.

—	A Standard	B Our experiment	Robson	Hobson and Hopkinson	Williams
	sq. feet	sq. feet	sq. feet	sq. feet	sq. feet
Area of grate, square feet,	28½	28½	32½	27½	22
Economic value of fuel or water evaporated from 212° by 1 lb., . .	lbs. 9·41	lbs. 11·15	lbs. 10·27	lbs. 11·08	lbs. 10·84
Rate of combustion per sq. foot of grate per hour, .	21·15	19·00	15·52	14·25	26·98
Rate of evaporation per sq. foot of grate per hour from 60°, . . .	cub. feet 2·62	cub. feet 2·93	cub. feet 2·14	cub. feet 2·18	cub. feet 4·04
Total evaporation in cubic feet per hour from 60°, .	74·80	79·12	69·52	60·03	88·96

SMALL FIRE-GRATES.

—	A Standard	B Our experiment	Robson	Hobson and Hopkinson	Williams
	sq. feet	sq. feet	Small grate not tried.	sq. feet	sq. feet
Area of grate, . . .	19¼	19¼		18¼	18
Economic value of fuel or water evaported from 212° by 1 lb. of coal, . .	lbs. 10·06	lbs. 12·58		lbs. 11·70	lbs. 11·30
Rate of combustion per sq. foot of grate per hour .	21·00	17·25		21·50	27·36
Rate of evaporation per sq. foot of grate per hour, .	cub. feet 2·909	cub. feet 2·995		cub. feet 3·49	cub. feet 4·31
Total evaporation per hour,	56·01	57·78		63·62	76·92

"61. With the above results before us we are unanimously of opinion that Mr. Williams must be declared the successful competitor, and we therefore award to him the premium of £500 which you offered by your advertisement of 10th May, 1855.

* * * * * * * *

"65. The results which we ourselves obtained exceed, in economic value of fuel, all the results of the experiments made with the competitors' plans. This was chiefly the case with the small fire-grates, and was due, in a great degree, if not altogether, to the smaller amount of fuel burned per square foot of grate per hour.

"The consequence of this was a more complete *absorption* of the heat generated, so that the products of combustion escaped from the chimney at a temperature lower by about 200 deg. when we obtained our best economic results, than they did during the trials of the competitors' plans. It must be remembered that this increase in the economic value of the fuel is obtained at the expense of the work done, but it is highly satisfactory to find that (as is shown in columns A and B of the last tables) *the great increase in the economic value is also accompanied with a decided increase in work done when perfect combustion is attained and smoke prevented.*

"66. We may now be expected to say a few words on the circumstances and mode of proceeding which we adopted, and by which we got the results contained in the columns marked B.

"They may be briefly described under these heads:—

"1st.—The fire-grate.

"2nd.—The fire-door.

"3rd.—The mode of firing.

"67. (1.) The fire-bars which we found most successful were cast about half an inch thick on the top, and as thin as possible at the bottom, and with the ends thickened up so as to leave about five-eighths or three-quarters of an inch air space.

"68. (2.) The fire-doors were the ordinary doors, perforated with horizontal slits about half an inch wide and 14 in. long, for the admission of air.

"69. (3.) Our mode of firing may be described as follows:—The coal was applied in charges of 1 cwt. each, and was all thrown on to the dead plate, which was 16 in. deep, and remained there until the furnace was again ready for charging. This coal, which had then, to a great extent, lost its hydro-carbons, was pushed forward with the rake, and a new charge thrown on the dead plate, to remain there until the furnace was again ready. The grates were always kept covered with ignited fuel to a depth of 10 in. to 12 in., and the furnaces worked alternately as nearly as convenient, although this was by no means of consequence as regards the prevention of smoke.

"70. All the ashes that fell through the bars were raked forward, and

thrown on to the fire with the fresh coals, so that the ashpit was kept clear and cool, and the whole of the cinders burned. The result of this was, that the average amount of ash to be removed from the ashpit and thrown away did not exceed 1·1 per cent. of the coal used.

"71. The amount of clinkers averaged about 1·85 per cent. of the fuel used.

"72. No stoking was required beyond occasionally gently raising the coals before firing with the poker, and it is worthy of remark that the heap of raw coal on the dead plate keeps the fire-doors perfectly cool.

"73. This mode of firing we find extremely efficient, and certainly requires nothing beyond such an amount of attention as may reasonably be expected from any working man of ordinary intelligence, and the actual labour is very much less than under the pernicious system to which men of this class are so wedded.

"74. The admission of air at the doors is simply an adaptation of the principle so long advocated by Mr. Williams, and we prefer his arrangement for this purpose, to that which we had previously used."

On receiving the report, the author was not a little surprised at finding a plan for smoke prevention, which seemed substantially the same as that which he had proposed, and which was rejected by the judges on such scant trial as not fulfilling the most essential condition of the competition, put forward by the judges as their own, as perfectly complying with all the requisite conditions of the trial, and the results of which, to use the words of the report, "exceed in economic value of fuel all the results of the experiments made with the competitors' plans." Accordingly the author wrote the following letter to two of the judges, viz., Messrs. Armstrong and Longridge:

"Ballast Office, Dublin, *Feb. 6th*, 1858.

"Sir,—I perceive by your second report to the Steam Collieries Association, that you obtained highly satisfactory results (marked B in the table) by the use of perforated fire-doors, combined with a mode of firing, which consists in coking each charge of coal on the dead plate previously to pushing it forward with the rake, when a new charge is thrown on the dead plate, to remain there until the furnace is again ready.

"As I naturally feel much interest in the subject, I should esteem as a favour your informing me in what essential respect the method you adopted differed from that proposed by me.

"I am, &c.,

"BINDON B. STONEY."

The replies to this letter were as follow:—

"ELSWICK ENGINE WORKS,
"NEWCASTLE-UPON-TYNE, *Feb. 9th*, 1858.

"SIR,—In page 21 of the reports to the Steam Collieries' Association you will find the method of firing to which you refer clearly explained. I do not think that anything that I could add would enable you more fully to discriminate between this method and that which you proposed.

"I am, Sir, &c.,

"W. G. ARMSTRONG.

"Bindon B. Stoney, Esq."

"18, ABINGDON-STREET WEST, 10*th Feb.*, 1858.

DEAR SIR,—In reply to your note of the 6th, I beg to say that the essential difference between the mode of firing which we found to succeed and that proposed by you was, that in the former the whole of the charge of coals was placed on the dead plate within the fire-door, whereas in your system it was partly within and partly without, upon your projecting shelf or hopper. In this case the coals do not part with their volatile constituents when they are pushed forward, and the result is, at each such time a considerable volume of dense smoke.

"I am, Sir, yours faithfully,

"J. A. LONGRIDGE.

"B. B. Stoney, Ballast Office, Dublin."

Now the author submits to the institution that the plan of smoke prevention proposed by him was in principle and substantially identical with that adopted by the judges as their own, and which they put forward as the mature result of their prolonged investigations.

In the plan proposed by the author, a large heap of coal is

placed *within* the fire-door, partly over an enlarged dead plate, partly over the front of fire-bars, and this heap is *backed up* by coal on the shelf, so as to allow the heap inside the door to be of large size without falling outwards, which it would otherwise do. If this back of coal were a mile long it would not affect the principle or action of the furnace, which consists in coking a large body of fuel in the front part of the furnace before shoving it forward with the rake, combined with the admission of air through perforations in door and door-box. The heap of coal which lies within the face-line of the boiler in the author's design exceeds in bulk 1 cwt. of coal; and it is obvious that a mass of fuel far exceeding that adopted by the judges may be heaped up within the mouth of the furnace, if such a course were found desirable.

The following extracts from the author's description laid before the judges in 1855, and from his letter to Mr. Reed in November, 1857, are, for the sake of comparison, placed in juxta-position with extracts from the judges' report, in which their plan B is described:—

Author's Description.	Judges' Report.
"When the fuel on the bars requires renewal, the *upper* and *front* part of heap is to be shoved forward and spread over bars. This being the coked, or partially coked, portion of heap, will not have the tendency to produce smoke that fresh fuel on the bars will have. The hinder portion of heap is then to be shoved into the front of heap, and fresh coal supplied to bring heap up to original size.	"69. (3.)—Our mode of firing may be described as follows:—The coal was applied in charges of 1 cwt. each, and was all thrown on to the dead plate, which was 16 in. deep and remained there until the furnace was again ready for charging. This coal, which had then, to a great extent, lost its hydro-carbons, was pushed forward with the rake, and a new charge thrown on the dead plate, to remain there until the furnace was again ready.

"The fuel on the bars may be a little deeper than is usual, owing to the partial coking which takes place before it reaches the bars.

"The fire-bars may be placed wide apart, since the coal is in coked lumps when it reaches the bars.

"One great collateral advantage of this method is the perfect coolness at the stoke-hole, for, since coal is a non-conductor of heat, none is transmitted from the furnace outwards through the outer portion of fresh coal."

"The grates were always kept covered with ignited fuel to a depth of 10 in. to 12 in.

"67. (1.)—The fire-bars which we found most successful were cast about $\frac{1}{2}$ in. thick on the top, and as thin as possible at the bottom, and with the ends thickened up so as to leave about $\frac{5}{8}$ in. or $\frac{3}{4}$ in. air space.

"72. No stoking was required beyond occasionally gently raising the coals before firing with the poker, and it is worthy of remark that the heap of raw coal on the dead plate keeps the fire-doors perfectly cool."

From this comparison it will be perceived that the results arrived at by the judges in their method of firing had been already foretold by the author.

The professed object of a competition such as that established by the Newcastle Collieries' Association is to arrive at truth; and it is for the furtherance of truth that the author has brought the subject before this institution, believing that the more such matters are ventilated the more will the real interests of the public, as well as of individuals, be advanced.

DUBLIN, *November* 17*th*, 1858.

[12th April, 1859.]

M. B. MULLINS, Esq., President, in the Chair.

On a NEW METHOD *of* SHORING *adopted in removing the two* LOWER FLOORS *of the* ROYAL BANK, DUBLIN.—By WILLIAM ANDERSON, Esq., Associate.

ABOUT a year ago the Directors of the Royal Bank, in this city, finding it necessary to construct a more extensive cash office to meet the requirements of their increasing business, invited several architects to lay suggestions before them as to the best means of accomplishing their object, and finally adopted the plan proposed by Mr. Charles Geoghegan, of Great Brunswick-street, and directed him to carry out his views.

The position of the Royal Bank in Foster-place, with regard to the surrounding premises, will be best understood by reference to the block plan (fig. 1), on which the darkly shaded portions indicate the walls that have been removed.

Mr. Geoghegan's proposition was to purchase the houses at the rere of the Bank, facing Anglesea-street, and construct one large and lofty room, stretching from it to Foster-place, by covering in the court-yard between the two houses, and removing the ground and first floor walls of the building in Foster-place.

The Directors perceived that this plan, though bold, and to a certain extent hazardous, was eminently calculated to afford the additional accommodation required, without interfering very materially with the business of the Bank, because neither the front in Foster-place would be disturbed, nor the basement and three upper floors rendered uninhabitable, during the execution of the works.

Still there were some misgivings as to the wisdom of attempting to remove the lower portions of eight walls, to do

which it would be necessary to support upwards of 200 tons, at an elevation of 40 feet above the basement story, and the author believes Mr. Geoghegan himself would have been slow to propose it, had not a novel and safe means of accomplishing his object presented itself to his mind.

Exclusive of the danger and unsightliness of settlements, almost sure to result, if it were attempted to support masses so rigid and friable as brick walls on elastic pillars of wood 40 feet long, there was the objection, that to get the shores put up, the whole of the ground and first floors would have to be removed, and the walls thereby deprived of valuable lateral support, where they were likely to be unduly strained by unavoidably unequal shoring. The expense also of providing suitable foundations for the shores, increased by the difficulty of getting such long and heavy timber into its place would have been very great.

As the beams A, C, and D (fig. 1), were all to be on the same level, and rigidly connected by bolts and rivets, it was very desirable, for facility of manipulation, to have them all loose in the walls at the same time. Had the system of timber shores been adopted, to attempt this would have been very hazardous, if not impossible, as the multitude of supports would have rendered the lifting and placing of the beams very intricate.

To overcome these objections, Mr. Geoghegan determined to make the lower portions of the walls, which he ultimately wished to remove, serve as temporary pillars to support the upper parts he wished to retain, by interposing frames of iron or wood, through which the beams could be passed. He accordingly explained his views to the author, and intrusted him with the construction of the shoring frame, which, it is thought, is a new feature in the art of building.

Exclusive of bolts, the frame is composed of four pieces (fig. 2), viz., the top and bottom, which act the part of short

beams, and the two sides, intended to carry the load as pillars. These may be of variable dimensions, to suit the depths of beam and thickness of walls or load to be supported; they are fitted together to make a truly rectangular frame, and held in position by means of bolts. The top and bottom are made cellular, with the outer walls thinner than the inner ones, in order to approximate as much as possible to the form of greatest strength, which would be a series of beams laid side by side I I I.

The vertical pieces are composed of plates stiffened by deep ribs, to obtain rigidity with lightness, and are provided with holes near the bottom, through which a rod may be passed, to carry a metal roller for the beam to run on when being pushed into its place.

As the frames had to be put up in inconvenient places, it was a great object to keep the several parts as light as possible, in order that three or four men might move them with ease, without having recourse to tackle. The frame the author has now the honour of exhibiting is one of those actually used at the Royal Bank, after having been tested with twenty tons in the centre, to carry which load it was designed, the members will therefore readily judge the facility with which it can be taken to pieces and erected in position.

There are two principal conditions under which beams may require to be placed under walls—

1st. There may be room enough to admit of the beam being launched into its place end on.

2nd. The wall may be so situated that the beam can only be got in sideways, or there may be a combination of the two cases, where there may be room to launch the beam half way if the previous half can be got in sideways. The one case requires a different form of frame from the other, as will now be explained.

Beam D (fig. 1), supporting two heavy chimney stacks, is

an illustration of the first case. There being plenty of room in the court-yard to lift the beam to its proper level, clear of all the houses, the following preparations were made:—

Two holes were broken through each of the two chimney stacks, and a good bed having been formed in each at the proper level, four of the frames represented in fig. 2 were placed in them. One smaller frame was similarly introduced in the intermediate wall. When all the frames had been carefully arranged in line, folding wedges of good dry oak were driven between the tops of the frames and the superincumbent walls, till the weight of the latter was made to rest entirely upon the frames. The intermediate portions of the walls and chimney stacks between the frames were then removed, and the beam having been hoisted on tall shear legs in the court-yard, to the proper level, was launched safely into its place through the frames.

Beam A (fig. 1), supporting the back wall, affords an example of the second case. The quoins of the adjoining house would not allow the beam to be hoisted sufficiently far back to pass it through frames similar to those used with beam D. It was, therefore, hoisted diagonally alongside the wall, till its end entered a doorway in the bow projection, which allowed it to go far enough forward to clear the quoins, when raised to a level, and placed at the proper height, parallel to its permanent position, and in which it was temporarily secured. Two frames (fig. 2) made to project its own width on one side of the wall, were inserted into holes, which had previously been cut in the brickwork, and bolted together so as to include the beam within themselves. The weight of the walls was transferred to the frames, and the portions between them cut away as before, and the beam moved in, first sideways, till fairly under the wall, and then launched forward through two more frames into its permanent position. To illustrate this more clearly, the model on the table has been constructed.

In fig. 2 is a representation of the frame used on this occasion. The top and bottom, being longer, were made deeper and stronger to carry the same load, and the vertical side, which was most severely strained on account of being immediately under the wall, was made double the strength of the outer pillar.

Beam C, which was got into the house with great difficulty, on account of its length, was laid on the first floor, alongside the wall it was intended to support, and raised thence to its proper height, where it was temporarily held while four frames were put round it, and secured in the wall in the manner already described. The intermediate masonry having been cut away, the beam was moved sideways into its place under the wall.

At this stage of the proceedings the three main walls, being completely cut through, were supported only on thirteen frames, in which the beams were lying loose, the latter were carefully fitted to each other and firmly secured by means of bolts and rivets, after which the whole mass of wrought iron, weighing 13½ tons, was adjusted to its exact position, vertically and horizontally. Chases were now cut in the lower walls to admit the columns, which, having been carefully erected, the weight of the walls on the frames was made to rest on the beams, by driving folding wedges between the top piece of the frame and the top of the latter, to cause the beams to deflect to their full extent previous to under-pinning with brick in cement between the frames. When this had been done, the wedges over the frames were cautiously slackened, and the entire weight of the building allowed to come upon the beams and columns. The frames were retained in position for a few days, during which the behaviour of the columns and their foundations was carefully watched, and as no signs of yielding were detected, the frames were released, the bolts connecting their several parts withdrawn, they themselves removed

piecemeal, and the gaps occupied by their upper portions made good in brick and cement. In this manner each of the eight walls was treated, most successfully, great care having been taken to insure the full weight of walls being placed on the beams before the underpinning was commenced, as any subsequent deflection would have caused the walls to crack.

Fig. 2, already alluded to, has representations of the frames used, with the weight of each part marked on it. As they were only required for temporary purposes, the castings were returned to the makers, and cost the builder only £5 per ton, at which rate, making allowance for fitting and bolts, the large frames cost £3 10s. each, the small ones £2 15s. each. Four men were able to put up three small frames in a day, at an elevation of 26 feet from the street, in holes prepared for them previously, and take them down again, at the rate of four a day, at a cost of 1s. per cwt.

The actual cost of the shoring upon the system described was £62, exclusive of breaking holes in the walls, and wedging upon the frames. The builder's estimate for the same operation, without any allowance for the great risk run, was £168 to £180, being a saving of at least £106 in favour of the frames, not counting the gain in time, security, and convenience. The urgent necessity of completing the work in the least time possible, induced the builders to use more frames than were absolutely necessary; had there been no occasion to shore all the walls simultaneously, the work could have been done for £42, or one-fourth the estimate quoted above.

The beams on which the walls now rest were all made of wrought iron, with plate sides stiffened by angle iron, most of them being double sided or box beams, and so proportioned that no parts in compression should be strained to more than four tons, and in tension to five tons to the square inch. They were all tested before leaving the works, in presence of the architect, or one of his assistants, by loading the centre of each

span to the extent of half the distributed load they were calculated to carry. As there is nothing remarkable in the details of their construction, the following table will give sufficient information respecting them :—

Letter of reference	Span	Depth	Load Beams are calculated to carry	Weight of Beams		
				cwt.	qrs.	lbs.
A	18′ 8½″	18″	68 tons	83	0	14
A	16′ 5½″	18″				
B	15′ 8 ″	18″	30 ,,	15	1	0
C	18′ 10½″	18″	80 ,,	74	0	0
C	16′ 5½″	18″	64 ,,			
D	18′ 0½″	18″	90 ,,	109	2	12
D	17′ 0 ″	18″	100 ,,			
E	16′ 0 ″	18″	34 ,,	9	2	0
F	18′ 6 ″	21″	58 ,,	33	2	0
J	18′ 5½″	18″	60 ,,	36	0	0

The figures in the fourth column, representing the load the beams were calculated to carry, are not the actual weight of walls resting directly on the beam only, but in addition the mechanical effect of the cross beams resting on the main girders, and throwing concentrated pressures more or less near the centres of the girders they rest on. The cost of erecting the beams at a height of 28 feet from the level of the street, including deterioration of tackle, amounted to £1 10s. per ton.

The design and execution of the columns was matter of the most anxious attention, on account of their unusual length, the great loads they were intended to carry, and the architectural necessity of diminishing their diameters to the utmost extent consistent with safety. The dimensions finally adopted were, length 26 feet, diameter of base 14 inches, diameter of head 12 inches, thickness of metal 1¼ inch. The ultimate strength of this pillar, according to Hodgkinson's practical adaptation of Euler's formula, was 770 tons, and the safe load may be estimated at one-sixth of that amount. Having decided the

proportions of the column, it was of the utmost importance to secure good sound casting, straightness, concentricity of bore to the external surface, and perfect bearing with flat ends on a good foundation. Soundness of casting and straightness were alone to be obtained by careful moulding and ventillation, but the certainty of obtaining uniformity of thickness required special precautions.

It is well known that in moulding columns the hollow part is formed by means of a "core," composed of a perforated metal pipe, wrapped with hay, and plastered with loam, till it assumes the proper shape and size. This core is placed horizontally in the external mould, and held securely in the sand at both ends, "chaplets," or supports of tinned iron, being placed in addition at intervals throughout its length. These chaplets answer very well for small castings, as the sand of the external mould into which they are stuck has sufficient power to resist the distorting action of the molten metal, but in columns of such length as those here described, they would not be sufficiently secure to be trusted. It was necessary, therefore, to make a metallic connexion between the top and the bottom boxes of the mould and the metal core barrel. This was done in the manner shown in fig. 3. A is the core barrel, with its envelopes of hay and loam; B the column when cast; K the boxes with the external mould; C is a metal chair resting on the cross ribs of the box, covered with about 1½ inch of sand; D is a metal trivet to support the core barrel, through the agency of the block E, which is buried in the hay and loam. On account of its great length the core had to be made in two pieces, and joined together in the centre when placed into the mould, when the two ends were supported by the method described. When the molten iron runs into the mould, the inferior specific gravity of the core causes a strong tendency to float, to prevent which a block F, similar to E, is buried in the hay and loam of the core; on this a

small pillar, G, whose length is of the exact thickness intended for the side of the column is placed, and kept down by the pillar H, and plate cramped to the top part of the external mould. By taking these precautions it was impossible for any irregularity in thickness of metal to-occur without the author's knowledge, as the position of the piece G, cast in, would betray it at once.

The strength of a column is very much influenced by the perfection of its bearing and fixity of its ends, and to ensure these the ends of the columns were turned truly in the lathe; and the base, which was two feet square, 3 inches thick, was turned on the upper and planed on the lower face. The foundation stone having been set perfectly level, and chiselled to fit the plate exactly, the latter was laid truly in its place, and secured by means of iron dowels run with lead. The upper face of the plate being level, the column when reared on it was of course quite vertical, and in absolute contact with the plate all round. The cap, which was also turned on its under side, was slipped in between the beam and the column, and the space between it and the beam filled with bars of flat iron, and cast iron cement tightly driven in. Both the cap and base had projections $\frac{1}{4}$ inch high entering the column to prevent any lateral displacement.

In conclusion, the author has to apologize if the members think that he has ascribed undue importance to the operations here described, the anxiety and attention they exacted have perhaps misled his judgment. The success which has crowned Mr. Geoghegan's bold design is in no small measure due to the intelligence and energy of the contractors, Messrs. Crowe and Sons, of this city, who did everything in their power to facilitate the introduction of this new system of shoring, and aid the author in the erection of the ironwork—operations which were not unattended by formidable danger.

[10th May, 1859.]

M. B. MULLINS, Esq., President, in the Chair.

On the Scales *of the* National Survey *of* Great Britain *and* Ireland.—By J. Ball Greene, Esq., Member.

The consideration of the scale for the National Survey, now in progress, has occupied so much attention of late, and being a subject with which this Institution is nearly allied, I beg to submit the following observations, with the view of laying the facts bearing on the subject before the members of the Institution, and of subsequently ascertaining their opinions thereon.

It may be desirable here to state that originally (in 1784) it was merely intended to make a general geographical map of these islands for military purposes, but as the work advanced and came into general use, it was considered that advantages, far beyond those contemplated in the first instance, might result from a national survey, and, consequently, in the year 1824, a Committee of the House of Commons recommended that the Survey of Ireland should be made and laid down on a scale of six inches to a statute mile, which was accordingly done, and I need not here refer to the care, accuracy, and beauty, with which that survey has been effected, its utility for the purposes contemplated, as well as for engineering uses, all of which are so well known to the members of this Institute. So far, this country had the advantage of England, for I believe that, with the exception of some of the northern counties, the maps were there made on a scale of *one inch to a mile*, thus rendering them useless for any purposes beyond those of general travelling or military maps. However, in 1840, when the Irish survey had been in operation, and its advantages had become generally known, the late Duke of

Wellington in that year recorded a minute stating, "*that if the nation incurred the cost of a survey, it ought to be of a kind most generally useful*," and in consequence of this observation an order was issued that the remainder of England and the whole of Scotland should be surveyed and plotted on the scale of six inches, as in Ireland. This work proceeded until 1851, when a Committee of the House of Commons sat to further consider the question, and in their report they pronounced in favour of a 1-inch scale, on the ground that it was better adapted for geographical purposes, and that the 6-inch map was not of sufficient public utility to justify such a large additional outlay as would be required to carry it out. Orders were, therefore, given to this effect, but the arrangement does not appear to have given satisfaction to our Scotch friends, and consequently, in 1852, numerous memorials were presented to the Treasury to rescind the order in favour of the 6-inch scale, which was accordingly done. All these orders and counter orders had the effect of attracting more public attention to the subject, and again, in 1853, numerous suggestions were made to the authorities, to the effect that a *larger* scale than the 6-inch for Scotland and the northern counties of England would be preferable. The Treasury, therefore, issued circulars to a number of scientific societies, and persons in the kingdom, inviting them to state their views on the merits of a 6-inch scale, as contrasted with any larger scale, and the preponderance of opinion being in favour of a larger scale, a second circular was issued to the same parties, requesting them to state what scale they would recommend. The replies were decidedly in favour of a 25-inch scale, or $\frac{1}{2500}$ part of the linear measure of the ground. Accordingly, in 1854, the Treasury determined that the Ordnance Survey should be conducted on that scale. In June, 1857, however, the subject was again brought under the notice of Parliament by an active and zealous Irish Member, whose views are strongly in favour of our Irish scale,

and on a division, after full discussion, the House of Commons rejected the 25-inch scale, considering the 6-inch preferable; and in consequence of this decision a Royal Commission subsequently sat to hear evidence, and report as to the best course to be pursued under these conflicting circumstances, and as that Commission has recently made its report, I have selected the present moment for bringing the subject before this Institution, with the object already stated.

Before entering on a consideration of the report in question, I will again epitomise the history of the National Survey, commencing in 1784 to the present, from which it will be observed that the conflicting orders issued from time to time must have greatly retarded the progress of this important work, and have added largely to the cost, viz.:—

In 1784, the National Survey was ordered to be made on a scale of 1 inch to a mile.

In 1824, the Irish Survey was ordered to be proceeded with on the 6-inch scale.

In 1840, the 1-inch scale in England was superseded, and six of the northern counties, and the whole of Scotland, were ordered to be made on the 6-inch scale.

In 1851, orders were issued that the remaining four counties of England and all Scotland should be on the 1-inch scale, and the 6-inch scale abandoned.

In 1854, it was determined that the scale should be 25 inches, or $\frac{1}{2500}$ part of the lineal measure of the ground. And in June, 1857, by a resolution of the House of Commons, that scale was condemned.

After all this we have now arrived at a crisis as regards this important work, and I therefore feel that the present is a proper time for a calm discussion of the merits of the report in question, and for eliciting the opinion of the members of this and similar institutions as to the best scale for a National Survey.

The Royal Commission, to which I have referred, was composed of the following eminent statesmen, and men of large scientific attainments and position, viz.:—

Lord Wrottesley	Mr. Vignoles
Earl of Rosse	Mr. Cardwell, M.P.
Lord Brougham	Mr. Turner
Professor Airy	Major-General Cameron
Sir Richard Griffith	Mr. M'Neill.
Mr. Brunel	

The Commissioners were empowered to inquire into and report upon—

1st.—The practical purposes which the National Survey should subserve.

2nd.—The progress which has been made in the survey, and the scales upon which the maps and plans have been drawn.

3rd.—The change in these scales, or in the details of the survey which should be made.

4th.—The cost of completing the surveys of England and Wales, Scotland, and Ireland, on the scales and in the manner which you recommend to be adopted.

The Commissioners have now made their Report, and they recommend—

1st.—That the 1-inch map of the United Kingdom be forthwith completed.

2nd.—That the survey of the northern counties of England and Scotland proceed contemporaneously, the cultivated districts to be on a scale of $\frac{1}{2500}$, and the whole on the 6 and 1-inch scales, except the Highlands of Scotland, which are to be on the 1-inch scale only.

3rd.—That the revision of the 6-inch plans of Ireland be completed.

4th.—The final question as to the extending the survey on the $\frac{1}{2500}$ to the whole of the United Kingdom, except Ireland, be left to the decision of the Legislature hereafter.

This Report, therefore, leaves the general question as to the best scale for a National Survey very much as it was before, except so far as it recommends that the northern counties of England, and the cultivated portions of Scotland, be surveyed on a scale of $\frac{1}{2500}$ of the lineal measurement.

We now come to the consideration of the $\frac{1}{2500}$ scale, and for a National Survey I am sure (let the profession say what it may) landed proprietors and the public at large will not object to it as being too small. This scale is equal to about $12\frac{2}{3}$ perches to an inch, which certainly is larger than is generally adopted for private surveys.

In this country we have found the 6-inch maps of the greatest public utility, and I feel that I cannot pay a higher tribute to their usefulness than has already been done by a member of the Royal Commission, Sir Richard Griffith, who, in a letter addressed to Lord Wrottesley, the Chairman, bears the following testimony to the great efficiency of the 6-inch scale for various important public purposes.

"I shall now state the several objects of a public nature which the general survey and valuation based upon it have subserved, commencing with the valuation.

"It is used for determining the amount payable by every townland and tenement for grand jury assessment, poor law rating, and other local taxes affecting lands and buildings. It is also used by the Government for ascertaining the amount of succession duty, and the income-tax is at present collected by it.

"In addition to the above, which may be viewed in the light of regular assessments and taxes, the Ordnance Plans on the 6-inch scale have been used by the Commissioners of Public Works in Ireland for all matters connected with the extensive operations of arterial drainage, which

comprehended the greater part of the lands liable to periodical flooding throughout the country, the limits of the greater portion of which had been originally surveyed, and were marked out on the plans by dotted lines, and thus, without incurring the expense of any special survey, the area of the lands injured by flooding or back water was at once ascertained.

"The numerous rivers and streams are also accurately laid down on the plans, and consequently nothing but levelling for the sections requisite to determine the amount of excavation necessary in each case, was required, to complete the surveyor's operations previously to the completion of the estimate and the commencement of the drainage works.

"Altogether there have been 121 drainage districts operated upon by the Board of Public Works, 110 of which have been completed, and final awards made and enrolled in the Rolls Court, and by means of the works, 175,443 acres have been relieved from flooding or injury from back water, at a cost of £1,097,296, nearly the whole of which sum has been advanced by the Treasury, under the authority of Parliament.

"The drainage documents enrolled consist of the printed award signed by the Commissioners, specifying the area of the land relieved, and the amount payable by the proprietor of each townland half-yearly, accompanied by sheets of the engraved Ordnance Plans on which the lands which have been improved are clearly shown by manuscript lines, and shaded by a distinguishing tint; and numbers corresponding with those on the printed award, are written in their proper positions on the Ordnance Plans.

"Here, then, we have the engraved Ordnance Plans employed in the most satisfactory manner, in enrolling and registering the lands which are liable for many years to pay half-yearly to the Treasury the instalments awarded towards the repayment of the loans made, for the purposes of the arterial drainage.

"In like manner the whole of the land drained or improved under the Landed Property Improvement Act (10 Vict., c. 32), and for which the sum of £1,490,000 has been issued, on account of upwards of three thousand separate loans, has been carefully laid down on the Ordnance Plans, on which all the drains sunk in every enclosure have been accurately marked by red manuscript lines, the lands which have been drained only, being distinguished from those which have been subsoiled, and from those from which rocks and large boulder stones have been removed, by separate colours, and these plans, with the statements of expenditure and reports of the Inspectors of Drainage relative to each loan, are registered at the Office of Public Works in Dublin, and reference to them is frequently

made by the heirs or remainder men of estates, of which portions have been thorough drained and improved under the Land Improvement Act, and for the repayment of the expenditure in which the lands are liable.

"In addition to the above, much advantage has been derived from the Ordnance Plans, as well as from the detail of the General Valuation of Ireland based on them, in the sale of estates by the Incumbered Estates' Commissioners, the biddings being usually made with reference to the amount of the annual value given in the valuation schedules, and the maps used at the sales are generally enlargements of the engraved Ordnance Plans.

"These plans have also been used with signal advantage by the several geologists who have been employed under Sir Henry T. de la Beeche and Sir Roderick J. Murchison, on the geological survey of Ireland, as by means of the minute accuracy in which every indentation of the coast, or change in the direction of every ravine, river course, or ridge of rocks is shown, the field geologist is enabled to lay down, with all the precision and accuracy of a special survey, not only every variation in the character of the rock, but the slightest change in the strike or dip of the beds, a circumstance most satisfactory to the individuals engaged in the geological examination of the country, and most useful when strata of economical value are traced, as in the case of beds of coal or of mineral deposits, &c., as well as most instructive and gratifying to the scientific geologist, who, for the first time, examines these unique surveys, which may be termed geological wonders.

"The Ordnance Plans have also been most useful to the nautical surveyors employed by the Admiralty in making the coast survey of Ireland, as not only is the shore in every case carefully and minutely laid down, distinguishing the rocky promontories and coasts from the tamer portions, as well as the banks composed of sand or mud, but by exhibiting all the striking objects near the shore to which angles may be taken, the surveyor is enabled to fix the place in which any rock, shoal, or channel may occur.

"It will be unnecessary to enter further into the advantages which the public have generally derived from the Ordnance Survey in Ireland, but it may be mentioned that nearly the whole, if not the whole, of the railways which have been executed have, in the first instance, had their respective lines laid down on the Ordnance Plans, without any special survey, except what may have been necessary to connect the levels taken for the purpose of ascertaining the excavations and embankments which would be required in forming the road according to the gradients decided on,

"It may also be observed that the landed proprietors have generally adopted these plans as general maps of their estates, and have used the valuation schedules, which contained the area of every tenement, as well as its relative value, as the ground work of their present rentals, increasing the amount of the valuation of each tenement by a proportionate addition or per centage, so as to meet their own views of the actual rent value.

"1. Thus it appears, in the first place, that the Ordnance Survey in Ireland has been used as the basis of the valuation, according to which all local taxes and assessments on lands are levied.

"2. For the collection of the income-tax and succession duty.

"3. As the test for the elective franchise.

"4. Saving the cost of special survey for the great arterial drainage.

"5. For the thorough drainages, &c., under the Landed Property Improvement Act.

"6. For the enrolment and registry of all the drainages, whether arterial or under the Land Improvement Act.

"7. For the purposes of the Incumbered Estates' Commission.

"8. For the geological survey of Ireland.

"9. For the nautical survey.

"10. For all railway surveys, &c., &c.

"11. For estate maps and valuations," &c., &c.

Thus Sir Richard Griffith sums up the various public and private purposes which our Irish Survey has subserved; and when we consider the great experience he has had in the use of it, his opinion must be considered as of the greatest importance.

In submitting to the Institution the result of my own observations, on the same scale, I may be permitted to state that I have now had very considerable practical experience, derived from my official connexion, for 15 years, with the Valuation and Boundary Survey Department, and I must record my opinion that for the purposes of the Tenement Valuation the scale of the Irish maps has been sufficiently large, the areas of all the tenements are computed from the paper, and it is very rarely that we have appeals against the areas so determined; if, therefore, the determination of areas

and laying down farm boundaries for valuation purposes, were the only objects contemplated in the construction of a national map, I would not hesitate in recommending the 6-inch scale in preference to a much larger; but if this country were now about being surveyed for the first time, would not a larger scale, as being more generally available for different uses, be preferable, provided the difference in cost was not excessive? This I conceive to be an interesting question, which might be profitably considered by this Institution, and in the consideration of it the following conditions appear to me to be those under which the choice of a scale should be made:—

1st.—That the scale shall be such that every definite linear space upon the map, shall be an aliquot part of the space upon the ground—for instance, the space upon the map which represents a mile shall be an aliquot part of the space upon the ground.

2nd.—That the scale shall be such that the fraction expressing the part of a mile upon the ground which the linear space representing a mile upon the map shall have for its denominator a number so constituted that equivalent quantity of the fraction expressed decimally shall be a finite or non-circulating decimal.

Parts of a Mile			Inches and parts of an Inch
Vulgar Fractions		Decimals	Decimals
1	$\frac{1}{1000}$	·001	63·36
2	$\frac{1}{1250}$	·0008	50·688
3	$\frac{1}{2500}$	·0004	25·344
4	$\frac{1}{5000}$	·0002	12·672
5	$\frac{1}{6250}$	·00016	10·1376
6	$\frac{1}{8000}$	·000125	7·92
7	$\frac{1}{10000}$	·0001	6·336
8	$\frac{1}{25000}$	·0004	2·5344

The 25-inch scale is that which has been adopted for the National Surveys of France, Belgium, Bavaria, Wurtemburg, and some other states in Europe, and though it has been accepted as the best, by the Brussels Statistical Conference, held in 1853, many practical men object to it as being inconveniently large for the ordinary purposes of engineering operations; however, I do not think that this is of so much importance. It has been stated by Colonel James, the Superintendent of the Ordnance Survey, that the difference in the cost between the 6-inch plans and the 25-inch plans is trifling, as compared with the accuracy and detail of the larger, which, I may observe, has the advantage, that on this scale the English acre is represented by the area of a square inch—the square 1·0018 inch represents an acre.

Colonel James states in his evidence before the Commission to which I have referred, that the cost per acre of the survey on the 25-inch scale would be 11¼d., while the actual cost of the plans on the 6-inch scale is 10½d. Therefore, if these figures be correct, and I have no reason to doubt their accuracy, I would prefer the large scale, as subserving a great many uses to which the small scale could not be applied, and, consequently, I am of opinion the Royal Commission acted wisely in recommending that the northern and unfinished counties of England and Scotland should be surveyed and plotted on the 25-inch scale.

The following is Colonel James' estimate:—

1. To complete the Survey of the United Kingdom on the 25-inch scale, ... £2,686,764
2. The completion of Great Britain on the 25-inch scale, and of Ireland with revision on the 6-inch scale, . £2,430,764
3. The completion of the United Kingdom on the 25-inch scale, except those parts already completed on the 6-inch scale, ... £2,285,129
4. The completion of the whole United Kingdom on the 1-inch scale only, ... £279,972

5. The completion of the survey, by surveying that part of the kingdom which has not yet been surveyed for the following scales, viz., cultivated parts for the 25-inch, moorland parts for the 1-inch, . . £558,072

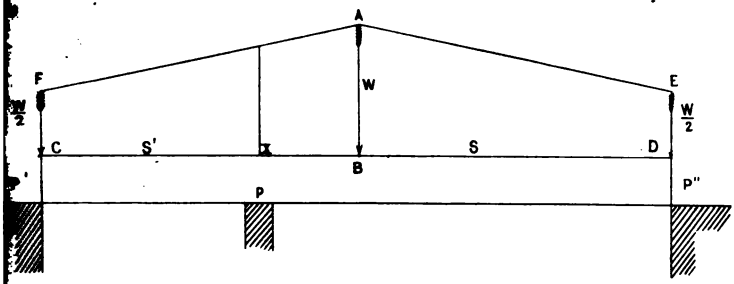
It therefore appears that, to complete the survey according to the recommendation of the Commission, a sum of over £558,000 is to be expended, and I find, on reference to the Report of the Commissioners, that their reasons for adopting the 25-inch scale are grounded on the following considerations.

1st.—That when the survey has been made in sufficient detail to be plotted on either the 6-inch or any larger scale, the additional expense of plotting on the 25-inch scale, instead of the 6-inch, bears an exceedingly small proportion; and

2nd.—That there are certain public objects which are better subserved by the 25-inch scale than the 6-inch, and some that can *only* be subserved by the largest scales.

In concluding this hasty sketch of the National Survey, I would desire to urge on the members of this Institution the importance of the work to them in their professional capacity, and to those who may follow us in after years in the same pursuits. Hence I think the subject is worthy of our consideration, and I trust that some of our members will favour the Institution with their views, in the hope that we may arrive at something approaching unanimity on a subject which, as I have shown, has been productive of so many conflicting views, and, consequently, of so much unnecessary delay and expense.

FIG. 1.



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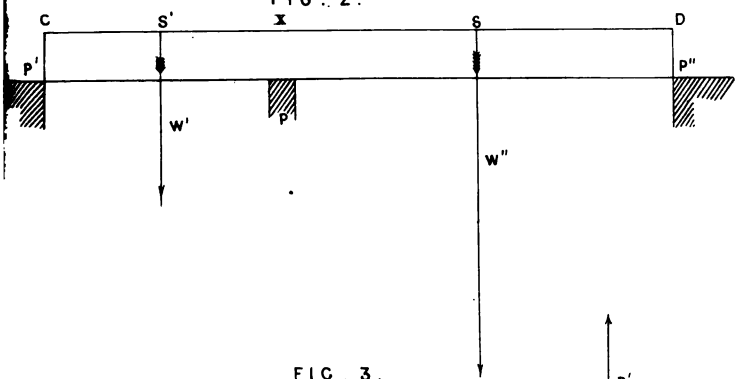

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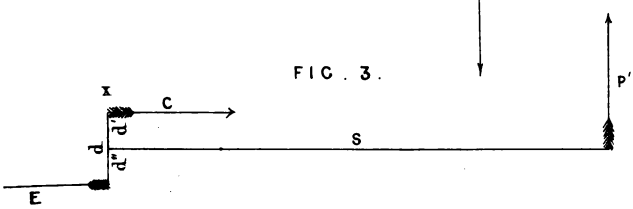

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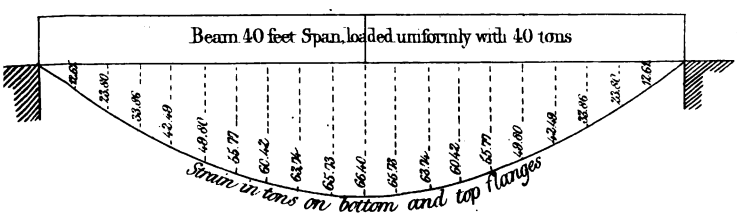
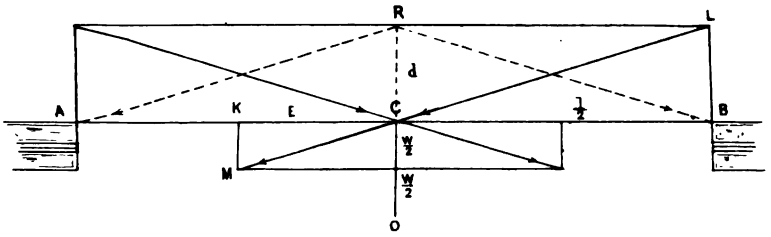


E.J. Harty Lith. 8, Dame St. Dublin.

FIG. 5.



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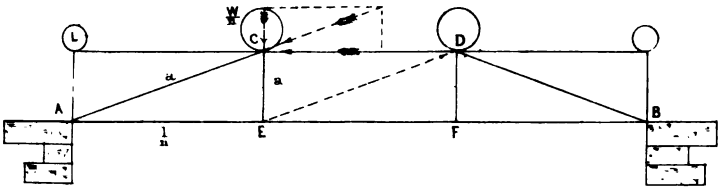

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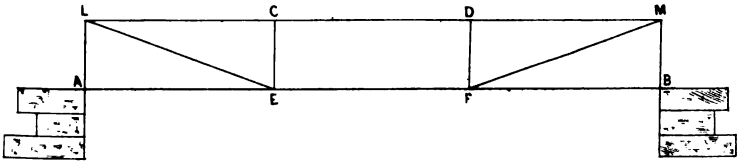

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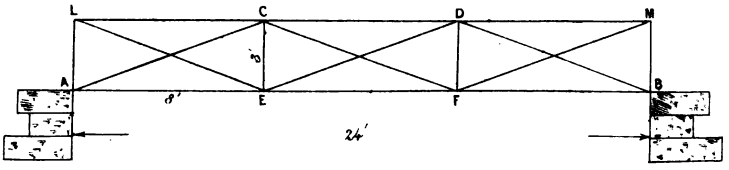

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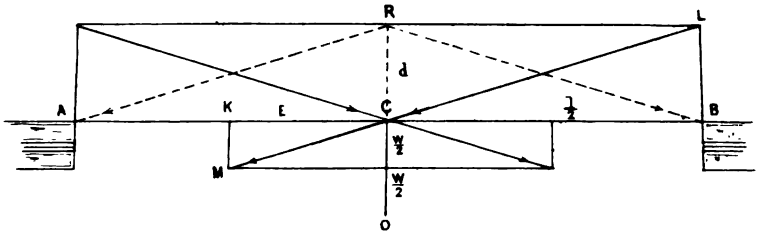

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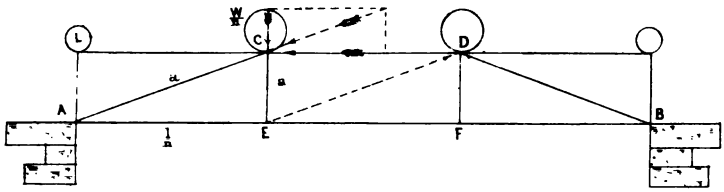

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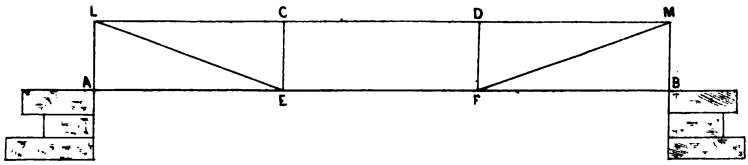

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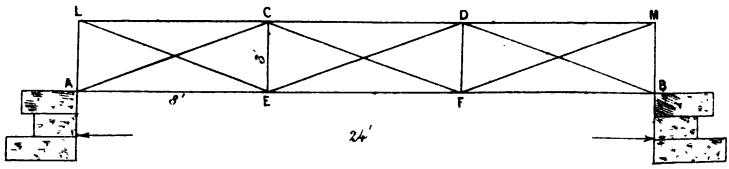

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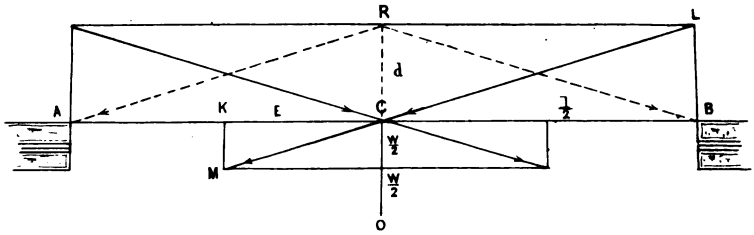

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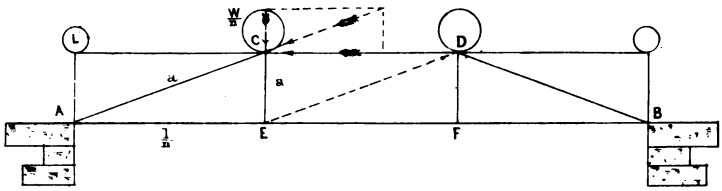

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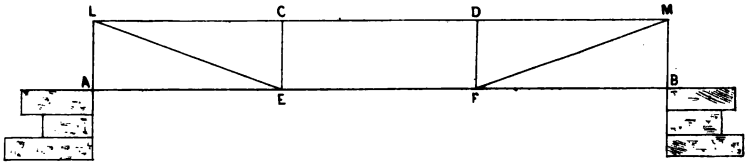

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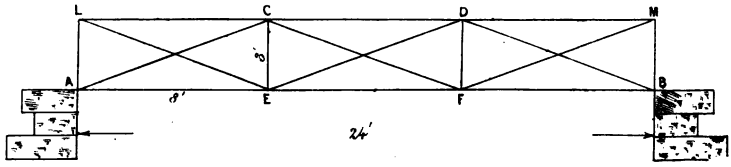


FIG. 11

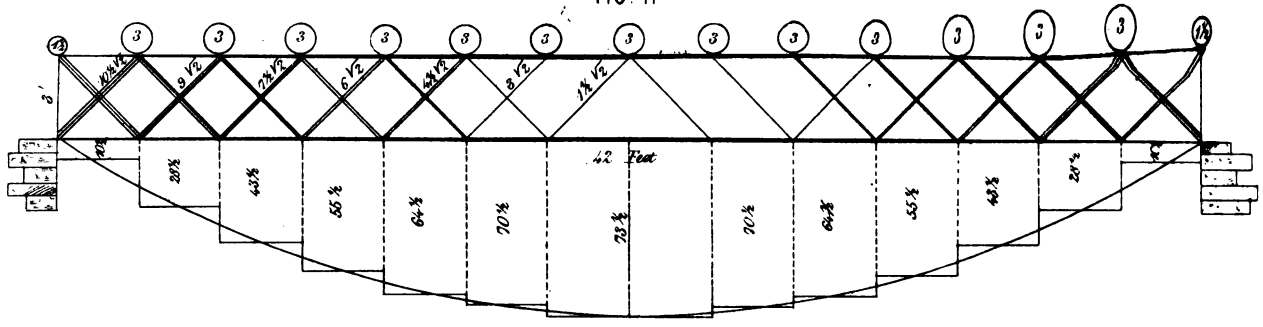


FIG. 12

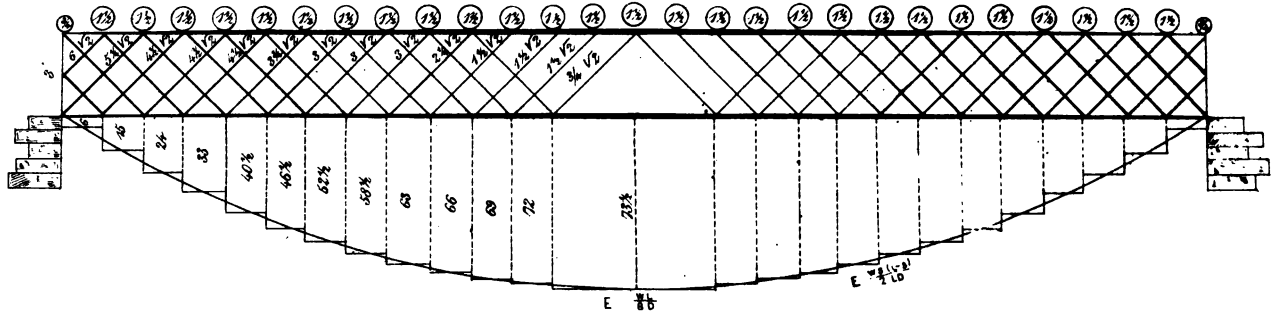


FIG. 11

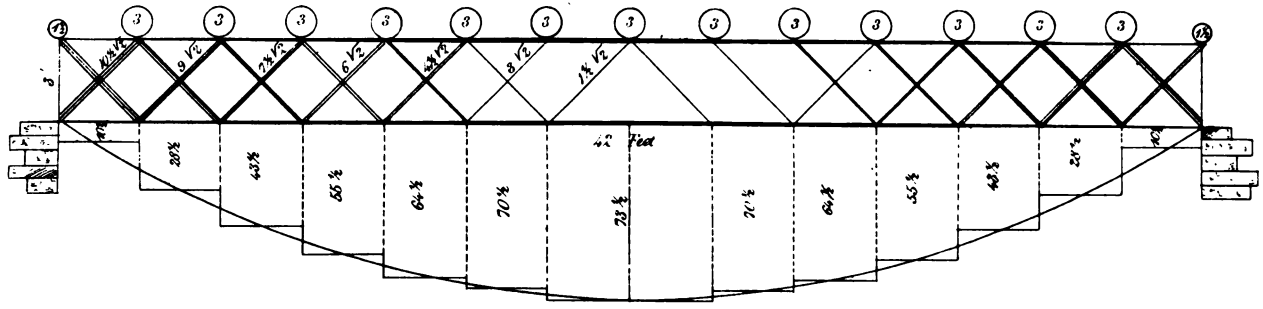

3
9 √2
7½ √2
6 √2
4½ √2
3 √2
1½ √2
20%
40%
55%
64%
70%
73%
70%
64%
55%
40%
20%
42 Feet

FIG. 12

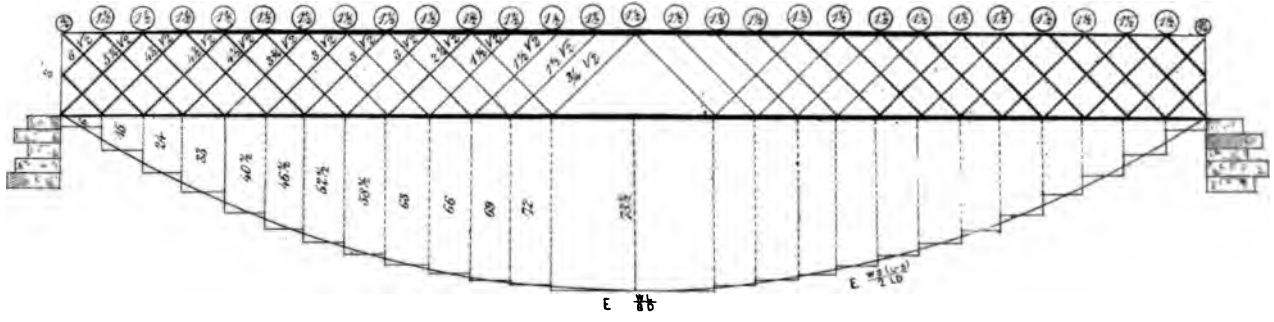
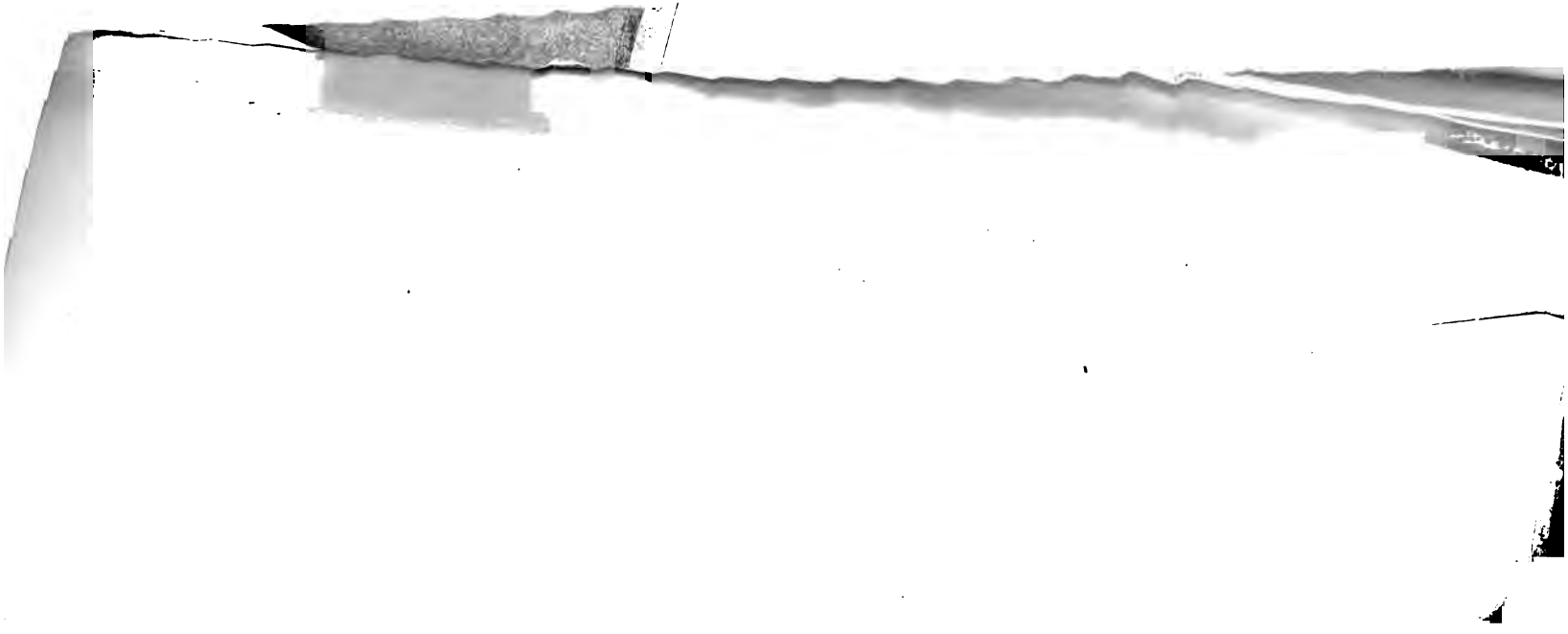

9 √2
3 3/4 √2
4½ √2
3 3/4 √2
4½ √2
3¾ √2
3 √2
9 √2
9 √2
2¼ √2
1½ √2
1½ √2
1½ √2
¾ √2
16
24
33
40%
46%
52%
56%
63
66
69
72
73%
E = 3/4 (w²/2 LD)
E 11/80

FIG. 1.



LIBRARY
ROCK AND
FOUNDATIONS

FIG. 1.

THE NEW YORK PUBLIC LIBRARY
REFERENCE DEPARTMENT

This book is under no circumstances to be taken from the Building

Form 410

MAR 2 4 19